H. Kofoe

Current
Ankle Art

Current Status of Ankle Arthroplasty

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HAKON KOFOED (Ed.)

Current Status of Ankle Arthroplasty

With 37 Figures

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Preface

The First International Congress on Ankle Arthroplasty took place in Copenhagen 20–21 June 1997. Internationally reknowned ankle surgeons from five continents discussed the current status of ankle joint replacement and arthrodesis. This book contains the proceedings.

Ankle arthroplasty has been in clinical use since 1970, and for 10–15 years was subsequently used as a treatment for painful and degenerated ankle joints. Hip and knee arthroplasty were established as routine methods during that same period, and arthrodesis of hip and knee became the exception. In the slipstream of these successes, several ankle-prosthesis designs hit the international market.

The initial results were described as promising. The majority of the patients experienced freedom of pain and retained some ankle joint mobility. However, the failure rate of these new implants became too pronounced after a few years of use. There could be several reasons for these mediocre results. Most designs called for rather excessive bone resections. Some prostheses were constrained, relying on the cement fixation in the fatty bone marrow above the subchondral bone level in the tibia. The multi-axial design had to rely on ligament stability. Non-congruent prostheses fared worse than congruent designs. The talus component was often placed on top of the talus dome. Thereby, the normal rotational axis of the ankle was changed. Impingement syndromes, abnormal gait patterns and, later, prosthesis loosening with gross loss of bone stock made it nearly impossible to perform revisions, and arthrodesis could be difficult to use as salvage procedures.

Subsequently, the treatment with an ankle prosthesis was reduced to very special cases. In retrospect, it would seem that these first attempts to replace the ankle joint were unsuccessful because they did not respect the anatomy, the kinematics, the alignment and the stability of the ankle joint. Ankle arthrodesis again became the gold standard.

While ankle arthroplasty generally was abandoned by the orthopaedic community, careful studies of normal ankle anatomy kinematics and previous failures resulted in the development of a new generation of ankle prostheses. These are characterised by preserving bone stock, respecting the normal rotational axis, tibiopedal alignment and by being non-constrained. They also use biological fixation. These attempts to improve ankle prosthesis and their results may not have resulted in the ultimate answer, but they have certainly started a new era and a genuine interest in ankle arthroplasty. It is our hope that these innovations will lead to results for ankle replacements

that are compatible with those of the successful replacements in other weight-bearing joints.

We are extremely grateful to all the contributing authors who, by giving and sharing their expert opinion in this book, have broadened the knowledge and the interest in treatment of the painful ankle. We also want to thank Springer-Verlag, Heidelberg, Germany, especially to Mr. Thomas Günther, for the extremely smooth and most effective handling of this presentation.

HAKON KOFOED Copenhagen, May 1998

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The Basics of Ankle Arthroplasty

CHAPTER 1

Kinematics of the Normal Ankle Joint

A. LUNDBERG

1.1 Introduction

The study of the kinematics of the ankle joint is hampered by several factors, notably:

- The kinematic complexity of the foot
- The inaccessibility of the talus

Due to these factors, a large proportion of kinematic knowledge of the ankle joint is based on studies of anatomical specimens. Most studies have used methods involving the application of bone-anchored optical markers, although radiostereometric analysis (RSA) has also been used (van Langelaan 1983). Over the years, a small number of in vivo studies using optical markers (Close et al. 1964) or RSA (Lundberg et al. 1989) have also been published.

1.1.1 Nomenclature

In this presentation, terms relating to movement will be used in the following way:

1. Plantar flexion/dorsiflexion will be used for rotation occurring largely in the sagittal plane, either around a strictly transverse axis or around an axis corresponding to the assumed "basic" ankle axis through the tips of the malleoli.
2. Inversion/eversion will be used for movement around an anteroposterior axis.
3. The term horizontal-plane rotation will be used to denote external/internal rotation around a vertical axis.

1.2 Basic Kinematic Properties

1.2.1 Tibiofibular Movement (Mortise Width Changes)

Most studies have shown a limited amount of mortise widening in dorsiflexion. There seems to be agreement that this widening is not always present in all individuals and that a decrease of the mortise width in plantar flexion may be more consistent (Svensson et al. 1989).

1.2.2 Joint Axis

From the traditional view of the ankle as a single-axis cylindrical hinge joint with a transverse axis, two main theories regarding the orientation of the ankle-joint axis evolved in the 1950s and 1960s. According to Barnett and Napier (1952) and Hicks (1953), there are two flexion axes: one running through the tips of the malleoli in the dorsiflexion part of the arc and one inclining inferiorly, medially during plantar flexion. According to the latter study, the anatomical background of this may be a difference in the curvature of the anterior and posterior parts of the talar trochlea. In a large study, Isman and Inman (1969) found no evidence of this, and concluded that the ankle joint is a single-axis conical hinge joint. This controversy has persisted, although most recent studies have assumed that the single-axis concept is valid.

In an in vivo study using RSA (Lundberg et al. 1989), we showed that both concepts may be equally correct. The variation in axis orientation seen in some individuals between plantar flexion and dorsiflexion could be explained by interaction between an oblique transverse axis as described by Inman (1976) and a vertical axis relating to the range of horizontal rotation that has recently been accepted as existing in the ankle. This would give the ankle joint the properties of an ellipsoid joint, albeit with a much smaller range of vertical- than transverse-axis rotation (Fig. 1.1).

1.3 Range of Motion

In several studies, the ankle range of motion has been assessed using different methods. Most of these studies have concentrated on the range of plantar flexion/dorsiflexion. However, in some, the distinction between the ankle and subtalar joints has not been made, and inversion/eversion or pronation/supination at the "ankle" has been included, although this movement would have been assumed to occur at the sub-talar and talonavicular joints. Horizontal-plane rota-

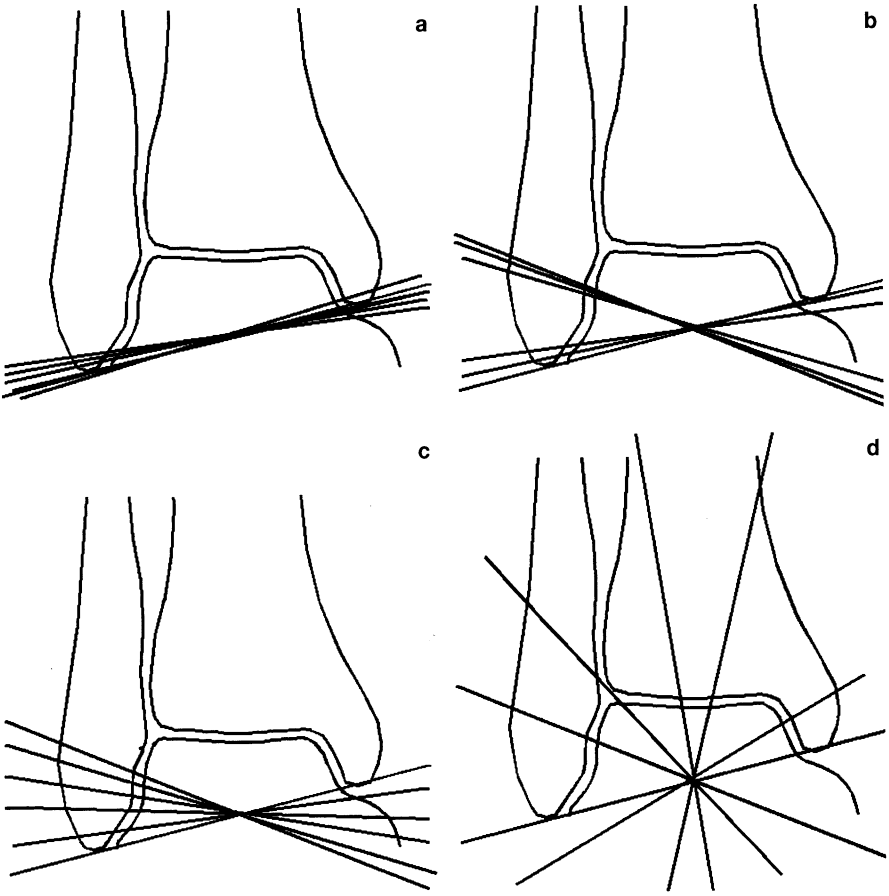


Fig. 1.1 a–d. Patterns of axis orientation including qualities of motion other than plantar flexion/dorsiflexion. Axes can have any orientation in a plane close to the coronal (a vertical plane through the malleoli). This may be explained by interaction between axes through the malleoli and vertical axis

tion is very difficult to assess at the ankle (tibiotalar) joint without access to the talus and has, thus, only been analysed in radiographic and/or invasive studies.

Observed average values in goniometric or radiographic studies range from 23° to 56° of plantar flexion and 13° to 33° of dorsiflexion with lower plantar-flexion values in radiographic studies (Boone and Azen 1979; Roass and Andersson 1982; Sammarco et al. 1983). The latter finding is consistent with the observation that movement distal to the talus will influence radiographic measurements and measurements performed under loaded conditions less often than unloaded clinical measurements.

As a reference, we studied the movement occurring when the angle between lower leg and substratum was altered from 30° of "plantar flexion" to 30° of "dorsiflexion"; thus, not a true assessment of range of movement. We found an average resulting rotation of approximately 50° with slightly more movement taking place in the plantar-flexion range (Lundberg, 1989).

1.4 The Ankle Joint in Walking

The properties of the ankle joint in walking are not fully understood for reasons stated previously. Methods for studying ankle kinematics in vitro in simulated gait are not validated. Studies performed in vivo are mostly based on non-invasive methods that do not take the position of the talus into account. In a study using electrogoniometry, Wright et al. (1964) assumed the existence of one ankle-joint axis and one sub-talar axis, the movement of which could be separated due to the difference in axis orientation. In an ongoing study, we have examined the kinematics of the ankle and sub-talar joints in walking, using reflecting markers on steel pins fixed to the tibia and the talus (Fig. 1.2). In three subjects, there was a fairly well defined pattern of plantar flexion/dorsiflexion over the stance phase (Fig. 1.3). The range used was usually less than 15°. The pattern of vertical-axis rotation was less consistent; however, the differences between the patterns of plantar flexion/

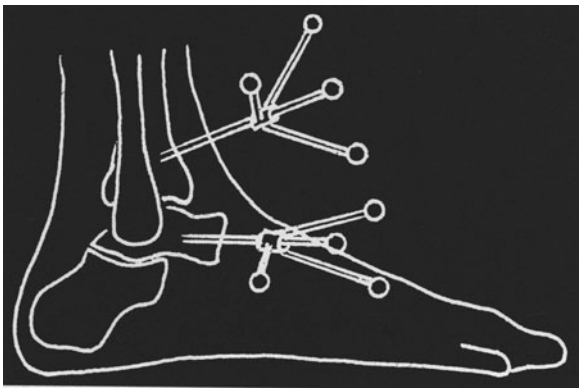


Fig. 1.2. Drawing of experimental set-up for an in vivo dynamic study. Steel pins with reflecting markers inserted into tibia and talus under local anaesthesia

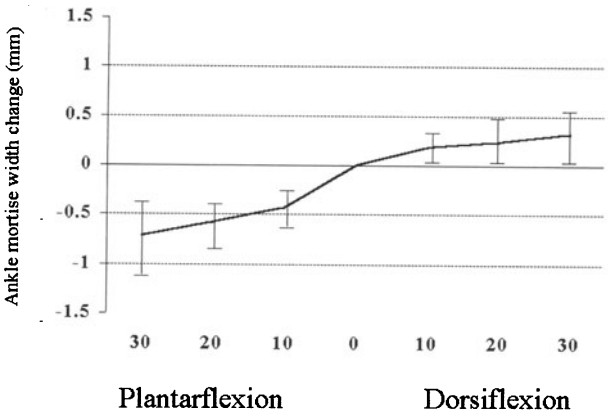


Fig. 1.3. Patterns of plantar flexion/dorsiflexion (*unbroken lines*) and horizontal-plane rotation (*broken lines*) during walking in three individuals. Values on horizontal axis demonstrate a percentage of stance phase

dorsiflexion and vertical-axis rotation clearly indicate that the rotation pattern is not only a function of the obliquity of the axis; this would have led to consistency and proportionality between the curves.

Thus, the ankle joint has shown different kinematic patterns in different studies. A large proportion of the differences noted can be explained by differences in the methods applied or in the kinematic situations studied. When allowance is made for these differences, there are some points that seem to be more or less undisputed in the modern literature:

1. The ankle joint may function as a single-axis oblique hinge in unloaded plantar flexion/dorsiflexion.
2. The orientation of the joint axis may vary among different movement ranges, particularly under loaded conditions and when horizontal-plane rotation is allowed to occur.

References

Barnett CH, Napier JR (1952) The axis of rotation at the ankle joint in man. Its influence upon the form of the talus and the mobility of the fibula. J Anat 86:1–9

Boone DC, Azen SP (1979) Normal range of motion of joints in male subjects. J Bone Joint Surg Am 61:756–759

Close JR, Inman VT, Poor PM, Todd FN (1967) The function of the subtalar joint. Clin Orthop 50:159–179

Hicks JH (1953) The mechanics of the foot. I. The joints. J Anat 87:345–357

Inman VT (1976) The joints of the ankle. Williams and Wilkins, Baltimore

Isman RE, Inman VT (1969) Anthropometric studies of the human foot and ankle. Bull Prosthet Res 10/11:97-129

Van Langelaan EJ (1983) A kinematical analysis of the tarsal joints. Acta Orthop Scand, Suppl 204

Lundberg A (1989) The kinematics of the ankle and foot. In vivo roentgen stereophotogrammetry. Acta Orthop Scand, Suppl 233

Lundberg A, Svensson OK, Németh G, Selvik G (1989) The axis of rotation of the ankle joint. J Bone Joint Surg Br 71:94–99

Roaas A, Andersson GBJ (1982) Normal range of motion at the hip, knee and ankle joints in male subjects, 30–40 years of age. Acta Orthop Scand 53:205–208

Svensson OK, Lundberg A, Selvik G (1989) In vivo fibular motion during various movements of the ankle. Clin Biomech 4:155–160

Wright DG, Desai SM, Henderson WH (1964) Action of the subtalar and ankle-joint complex during the stance phase of walking. J Bone Joint Surg Am 46:361–382

CHAPTER 2

Why an Ankle Arthroplasty?

L. KLENERMAN

In an era of joint-replacement surgery, ankle procedures have failed to achieve what has been accomplished with other joints; John Charnley turned to a hip arthroplasty after failure of his compression arthrodesis. In a similar manner, ankle arthrodesis is at present the most commonly used procedure for the painful stiff ankle. A unilateral ankle arthrodesis results in good function, provided the sub-talar and mid-tarsal joints are normal and provide a compensatory mechanism.

The disadvantages of arthrodesis include the need for prolonged immobilisation in a plaster cast and a pseudoarthrosis rate of at least 10%. There is no compensatory mechanism if the mid-tarsal and sub-talar joints are involved by degenerative changes and there is increased stress on other joints of the lower limb. In contrast, total-ankle replacements relieve pain and provide a functional range of movement.

The present state of ankle arthroplasty has been well summarised by Roger Mann (1984) who wrote "Most total ankle joints in use do not provide adequate pain relief, significant improvement in motion or long-term reliability". This statement is supported by a recent review from the Mayo Clinic (Kitaoka and Patzer 1996) where, of 160 ankle arthroplasties, there were 57 (36%) failures and 31 (19%) good results. There were 55 (34%) fair and 17 (11%) poor results. The overall conclusion was that the Mayo total ankle arthroplasty was not recommended. The late Kenneth Johnson suggested the ideal case is a patient with rheumatoid arthritis (not on steroids), a painful stable ankle with good quality bone, no hind-foot valgus or varus and a restricted activity level.

A variety of arthroplasties are available. There are two-component prostheses that may be either constrained, as in the Mayo Clinic ankle (1976); semi-constrained, as in the Mayo Clinic ankle (1989) or the Imperial College London Hospital (ICLH) ankle; and unconstrained, as in the Bath and Wessex ankle. There is also the three-component prosthesis (with a free-gliding core or disc) as in the Scandinavian total ankle replacement (STAR) prosthesis. It is this latter type which addresses the problem of the element of rolling at the ankle and has shown excellent results so far. In some respects, the STAR ankle has contours similar to that of the sheep, where the ankle joint is restricted to flexion and extension partly by an anteroposterior flange that projects from the tibia into a slot in the talus. It appears to have overcome the problem of restraint of rotational movement which, otherwise, leads to increased stress at the bone-cement interface.

The need for a mobile ankle or imitation of ankle movement is also illustrated in the construction of below-knee prostheses for amputees, such as in the Jaipur Foot or Seattle Prosthesis. In the same manner as the knee joints that started off as pure hinges, as in the Waldius knee, the ankle joint has now moved onto a replacement that allows an element of rolling at the joint. This modification has produced the best results so far.

Evidence for the superiority of arthroplasty over arthrodesis has been provided by Kofoed and Stirrup (1994). In a series of 26 patients treated for osteoarthritis of the ankle, 13 patients with 14 arthrodeses were compared with 13 patients with 14 ankle arthroplasties. The median follow-up was 84 months. Ankle arthroplasty gave better pain relief, better function and a lower infection rate without development of sub-talar arthritis.

There is reason to believe that replacement of an ankle has moved from the stage of an experimental and occasionally successful procedure to that of a worthwhile and durable solution. No arthroplasty can be accurately assessed without a minimum 5-year follow-up. Time is needed for the true picture to emerge, but there is the prospect that ankle arthroplasty will soon take its place alongside other well-tried and accepted procedures in the hip and knee. We are now on the threshold of a period where the superiority of ankle arthroplasty, in contrast to arthrodesis, will be firmly established and become a standard part of the orthopaedic surgeon's repertoire.

References

Johnson KA (1989) Surgery of the foot and ankle. Raven, New York, p 278

Kitaoka HB, Patzer GL (1996) Clinical results of the Mayo total ankle arthroplasty. J Bone J Surg Am 78:1658–1664

Kofoed H, Stürup J (1994) Comparison of ankle arthroplasty and arthrodesis. The Foot 4:6–9

Mann RA (1984) Osteoarthritis of the foot and ankle. In: Moskowitz RW, Howell DS, Goldberg VM, Mankin HJ, Saunders WB (eds) Osteoarthritis diagnosis and management. Saunders, Philadelphia, p 394

CHAPTER 3

What Went Wrong with the First Generation of Ankle Arthroplasties?

W. A. SOUTER

3.1 Introduction

Ankle arthroplasty is currently regarded by the majority of orthopaedic surgeons as an operation which, in view of the alleged virtues of arthrodesis, is at best irrelevant and at worst somewhat disreputable; perhaps even unethical in view of the severe complications that may result! Comments in the literature tend to range from total disparagement of its use in osteoarthritis or even in rheumatoid arthritis to a grudging concession that with improved technique, it might come to have a place in the management of the severely disabled rheumatoid arthritic patient [1, 2, 4–6].

Normal hind-foot function and normal gait demand fully coordinated action in the ankle, sub-talar and mid-tarsal joints. A healthy and fully mobile mid-tarsal joint can, however, compensate to a large degree for loss of ankle movement. Thus, in many post-traumatic problems, an arthrodesis can leave the patient with a remarkably normal gait [3, 7]. In most rheumatoid arthritic patients, this potential functional reserve is no longer available and the whole hind-foot complex and ankle might become largely ankylosed.

3.2 Ankle Arthroplasty

One of the earliest arthroplasties introduced by Richard Smith attempted to restore composite ankle and hind-foot movement through ball and socket articulation. However, some patients found this implant inherently unstable and, thus, failed to regain satisfactory confidence in walking [3]. Kirkup has pursued this approach via the Bath and Wessex prosthesis with greater success by reversing the high-density polyethylene and metal articulations and by tensing the ligamentous support by means of graded thickness of the talar domes (2–6 mm). Nevertheless, there have continued to be considerable complications with this technique.

In a recent review, Kirkup found that of 51 Bath prostheses available for follow-up, 44 (86%) were in situ at an average of 4.2 years, and 32 (63%) were

either free from pain or experienced only mild discomfort after activity – none experienced severe pain. Most had radiolucent lines without symptoms, six were under observation for loosening, while two were revised and one underwent arthrodesis for loosening. This led him to the cautious conclusion that, for severely disabled rheumatoid arthritic patients with bilateral, tarsal ankylosis and crippling ankle pain, spherocentric joint replacement is justified on one side and sometimes on both [5]. It seems that the idea of substituting a simple ball and socket mechanism for a two-tier and highly complex axial arrangement of joints may be much too simplistic to achieve success.

At the other extreme, the Oregon ankle attempted to replace the entire ankle mortise. The increased constraint and displacing forces inherent in such a design, especially in the presence of a mobile inferior tibio-fibular joint, led to such a high incidence of loosening that this prosthesis met with a fairly rapid demise.

The more common approach was to resurface the dome of the talus with a curved metal plate and the plafond of the tibia with a concave surface of high-density polyethylene, with both components of the joint being secured with cement. Examples of such prostheses are the Liverpool, Mayo, Imperial College London Hospital (ICLH), and TPR (Thompson, Parkridge and Richards) implants. My own experience of the first generation of ankle arthroplasties was based on the latter. Between 1977 and 1986, 32 of these arthroplasties were carried out in 24 rheumatoid arthritic patients, 17 of whom were seropositive, 5 seronegative, and 2 suffering the late effects of juvenile chronic arthritis. Their ages ranged from 30 years to 79 years (mean 50 years). A review of this series was carried out in 1988 when the follow-up varied from 2 years to 11 years (mean 5.7 years) [8].

Pain relief had been remarkably satisfactory. Prior to surgery, all 32 joints were the seat of severe pain. At 1 year after surgery, 25 joints were completely pain free, 2 were subject to only occasional twinges of pain, and a further 4 were only affected by mild pain; only 1 joint was still the seat of severe pain. However, what was even more impressive was that in the 15 joints followed for 8 years or more, the results remained fairly satisfactorily consistent, with 10 of the 13 having no more than mild pain.

With regard to walking ability, there had also been quite dramatic improvement. Prior to surgery, only 4 of the 24 patients had been able to walk more than 100 yards, whereas at 1 year after surgery, 17 were in this category. Moreover, at the final follow-up, averaging 5.7 years, ten patients were still able to walk a quarter of a mile or more, although considerable fall-off in walking performance had occurred, as might be expected in the presence of chronic inflammatory polyarthritic disease.

3.3 Complications

Unfortunately, in spite of relatively satisfactory results with the surgery, there was an alarmingly high incidence of complications which included:

Delayed wound healing
Fibular impingement
Radiological loosening
Clinical loosening
Stress fracture of the lateral malleolus and complete disintegration of the arthroplasty with subluxation of the ankle.

3.3.1 Delayed Wound Healing

This proved a very frustrating and potentially dangerous problem with the central section of the anterior, longitudinal incision breaking down and sometimes taking weeks to heal or even requiring a skin graft. Initially, we had been using an approach lateral to the extensor *hallucis longus*, with retraction of the main neurovascular bundle medially. In 15 cases, in which this approach was used, only 5 achieved primary healing, while 3 eventually required a skin graft. In the subsequent 17 cases approached, in a slightly more medial plane between the extensor *hallucis longus* and the tibialis anterior, primary healing was achieved in 12 cases, and only 1 case required a skin graft.

3.3.2 Fibular Impingement

Fibular impingement can be a very painful complication, nullifying the initial good results. It arises from progressive valgus of the hind foot due either to a sub-talar deformity or to recurrent angular wedging of the ankle mortise (Fig. 3.1). Temporary improvement may be obtained by resecting the distal extremity of the lateral malleolus, but a definitive solution may require triple fusion.

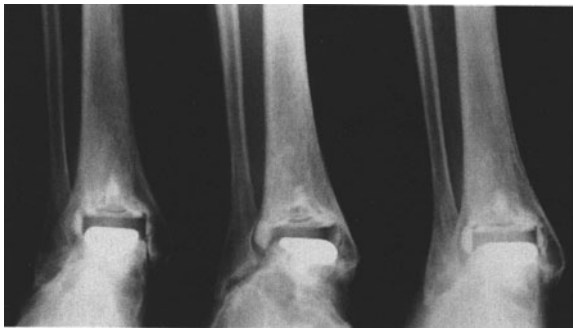


Fig. 3.1. X-rays showing increasing impingement of fibula over a period of 5 years as a result of progressive valgus deformity of the hind foot

3.3.3
Radiological Loosening

All subjects showed significant and progressive cement lines around the tibial component within 2 years. There was a suspicion that a pre-operative ball and socket erosion seemed to predispose to rapid radiological loosening.

Fortunately, significant radiological loosening proved to be compatible with a successful clinical result, provided the tibial component remained plantigrade and symmetrically placed within the ankle mortise.

3.3.4
Clinical Loosening

Symptomatic clinical loosening seemed most likely to occur with uncorrected valgus of the hind foot or in patients who previously had a wedge deformity of the ankle, probably as a result of the continuing action of the uncorrected forces which had caused the initial problem.

3.3.5
Stress Fracture of the Lateral Malleolus With Subluxation of the Ankle

The ultimate disaster in the presence of severe valgus of the hind foot is a stress fracture of the lateral malleolus, which results in complete displacement of the tibial component of the prosthesis and subluxation of the ankle (Fig. 3.2). These are disastrous complications and it was after the occurrence of two such complications in our own series that we temporarily abandoned ankle arthroplasty in the management of our rheumatoid arthritic patients. In both of these cases, we were able to restore stability by the insertion of a Gross-Kempf nail with massive grafting of the defect between the talus and tibia, using an appropriately contoured femoral head and morselised bone. One of the patients who was already suffering from severe cervical myelopathy died some months later before healing was achieved. In the other patient, although bony union did not occur, a stable pain-free fibrous union was obtained.

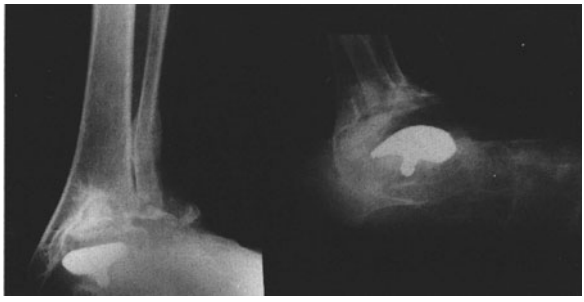


Fig. 3.2. Complete failure of ankle arthroplasty as a result of loosening and proximal migration of tibial component and stress fracture with disintegration of the lateral malleolus, occurring only 2 years after surgery

4
Indications for Ankle Arthroplasty

Prior to this review, it was my impression that ankle arthroplasty was indicated mainly in the very disabled rheumatoid arthritic patient, who would not subject the prosthesis and its fixation to too much punishment. It appears, however, that this may not be the case. Common findings in many severely disabled rheumatoid arthritic patients, such as severe valgus of the hind foot, ball and socket erosions, valgus/varus wedging of the ankle mortise, severe osteoporosis and arthritis mutilans, would all seem to be definite contraindications. Conversely, the reasonably active rheumatoid arthritic patient, with good bone and a foot showing little or no valgus deformity or angulation within the ankle mortise, may well constitute the ideal subject for this operation.

5
Summary and Conclusions

1. In view of the very significant compensatory movement that can be developed within a healthy mid-tarsal joint, ankle arthroplasty may be unnecessary and inadvisable at its present stage of evolution in post-traumatic arthritis.
2. Aiming for restoration of both ankle and hind-foot mobility in one implant is probably impracticable and biomechanically unsound.
3. Total resurfacing of the ankle mortise should probably not be attempted, unless a formal fusion of the inferior tibio-fibular joint is part of the operative procedure.
4. Arthroplasty should be avoided in the extremely disabled or immune-compromised patient, in the presence of severe osteoporosis or arthritis mutilans, and in the presence of uncorrected valgus deformity.
5. The ability to restore ankle movement in rheumatoid arthritis remains a very worthwhile goal and, at the present moment, the concept of a prosthesis incorporating a meniscal bearing seems to be the most attractive line of research with hope of achieving success.
6. The ideal patient may be one who is still quite active, has a plantigrade foot and ankle mortise, and who is not showing excessive osteoporosis or any tendency to arthritis mutilans.

References

1. Bolton-Maggs BG, Sudlow RA, Freeman MAR (1985) Total ankle arthroplasty. A long-term review of the London Hospital Experience. J Bone Joint Surg Br 67:785–790
2. Cracchiolo A (1993) The rheumatoid foot and ankle: pathology and treatment. The Foot 3:126–134
3. Demottaz JD, Mazur JM, Thomas WH, Sledge CB, Simon SR (1979) Clinical study of total ankle replacement with gait analysis. J Bone Joint Surg Am 61:976–988
4. Hamblen DL (1985) Can the ankle joint be replaced? (editorial) J Bone Joint Surg Br 67:689–690
5. Kirkup J (1990) Rheumatoid Arthritis and ankle Surgery. Ann Rheum Dis 49:837–844
6. Lachiewicz PF, Inglis AE, Tanawat CS (1984) Total ankle replacement in rheumatoid arthritis. J Bone Joint Surg Am 66:340–343
7. Mazur JM, Schwartz E, Simon SR (1979) Ankle arthrodesis. Long-term follow-up with gait analysis. J Bone Joint Surg Am 61:964–975
8. Souter WA (1988) Arthroplasty or arthrodesis. Paper presented to the Rheumatoid Arthritis Surgical Society, London, November 1988

CHAPTER 4

Ankle Arthroplasty: Indications, Alignment, Stability and Gain in Mobility

H. KOFOED

4.1 Introduction

There were several reasons for the failures of the first-generation ankle arthroplasty. The indications were not clear and the incidence of prosthetic loosening was rather high in some constrained devices [1, 2, 3]. With other designs, the spheroid types, the kinematics of the ankle joint were entirely dependent on the ligament structures [4, 5]. Such prostheses' inability to correct deformities and produce stable and cylindrical mobility in the ankle joint were generally the problems. Calderale and Pipino [6] and Pappas et al. [7] were the first to describe biomechanical features of ankle prosthesis. The principles were: (1) to preserve the axis of the ankle joint, (2) to let the prosthesis be as anatomical as possible, (3) to avoid constrained designs, and (4) to get cylindrical motion. These principles have been followed in the Scandinavian total ankle replacement (STAR) prosthesis. Furthermore, as the ankle joint is a three-compartmental joint, the joint spaces between the medial- and lateral-talus facets and the malleoli must be addressed.

4.2 Material and Methods

From 1986 to 1996, I have performed more than 200 meniscal-bearing nonconstrained ankle arthroplasties. A prospective series from Copenhagen represents 76 cases. The experience gained by analysing these cases clinicoradiographically at yearly follow-ups have clarified the indications and contraindications, the alignment procedure, the stability problem and how to restore mobility. All cases were evaluated clinically using the KAS (Kofoed ankle score) [8]. There was a female:male ratio of 41:35. The patients median age was 56 years (range 29–83 years). The diagnoses were osteoarthritis (OA), 44 ankles; rheumatoid arthritis (RA), 22 ankles; talus necrosis, 4 ankles; psoriatic arthritis, 4 ankles; and conversion of one previous ankle fusion.

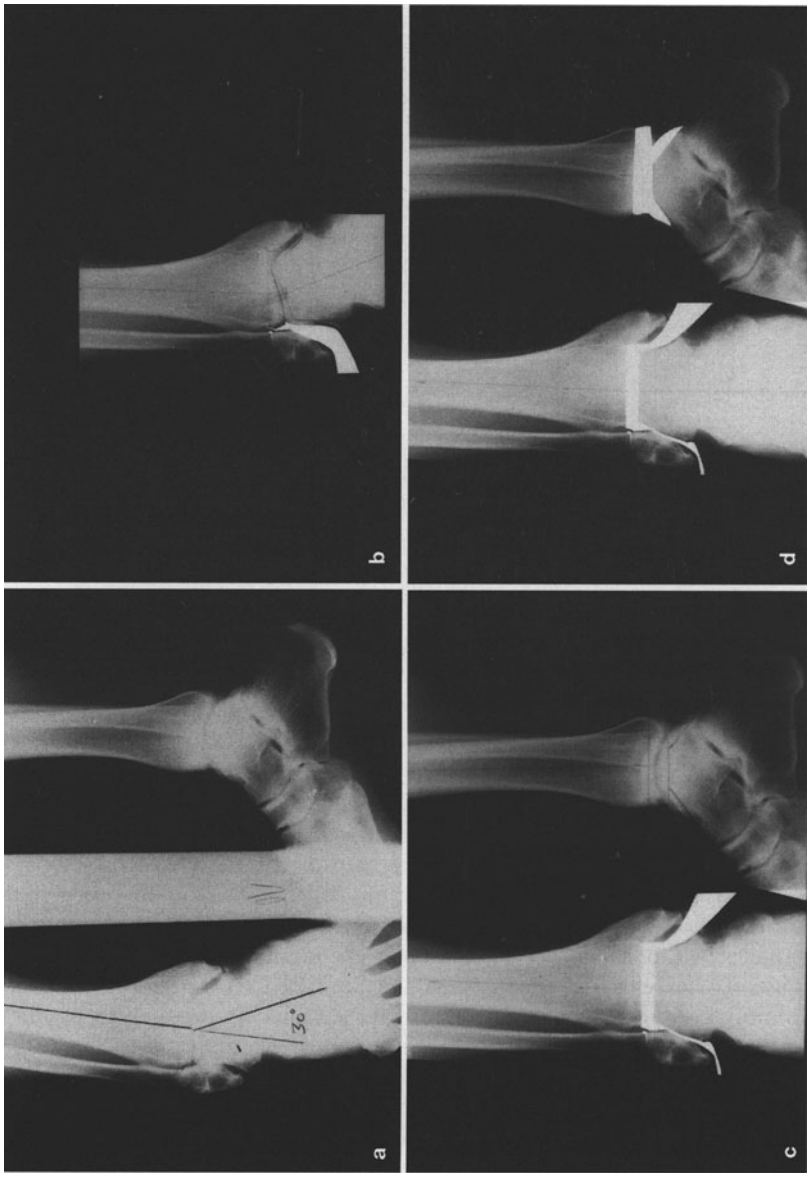


Fig. 4.1a–d

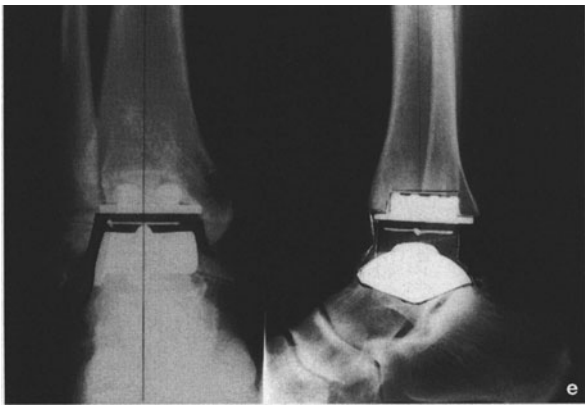


Fig. 4.1 a–e. **a** 30° Varus ankle after open-reduction internal-fixation (ORIF)-treated malleolar fracture. **b** Marking of the distal cut in the tibia and fibular osteotomy. **c** Rotation of the talus within the mortise. An additional cutting of the medial-talus facet if necessary, to obtain full rotation to neutral. **d** The normal talus cuts are performed after the alignment procedure. **e** The prosthesis has been inserted

The tibio-pedal axis was measured on the antero-posterior (AP) view of radiograms between the long axis of the tibia and the axis of the talus. A normal axis was said to exist if within 5° valgus and 3° varus. These measurements were repeated at follow-up.

During the operation, the anterior and posterior lip of the distal tibia was cut off tangentially to the axis of the tibia. The talus could then be rotated within the mortise to align the axis. Sometimes this was not possible without resecting a few millimeter slices along the medial or the lateral facets or a prominence of the talus dome. However, no further talus cuts were performed until the axis had been corrected and a free arc of motion within the ankle mortise was possible. When this was accomplished, the most prominent 4 mm of the talus dome was resected parallel to the distal tibial cut, while holding the foot in neutral position with the talus pressed up against the flat tibial surface. Fig. 4.1 a–e shows an example of this sculpturing technique. In the case of instability, i.e., tilting of the meniscus, this was always caused by lacking lateral ligaments. These were restored by use of the peroneal brevis tendon as an active ligament, i.e., it was taken off the base of the fifth metatarsal and out behind the lateral malleolus. After a tendon split, both parts were taken through drill holes in the lateral malleolus. One part was used as the anterior-talofibular ligament through drill holes in the talus; the other part was used as the posterior calcaneofibular ligament and was fixed in the lateral calcaneus. If only one of the ligaments had to be repaired, one half of the tendon was reinserted on the fifth metatarsal base. Fig. 4.2 (*left*) shows a case in which, after 7 years with an ankle prosthesis, the patient accidentally ruptured his lateral ligaments. The tilt is obvious. The ligaments were reconstructed to stabilize the ankle. Fig. 4.2 (*right*) shows the result 1 year after the reconstruction.

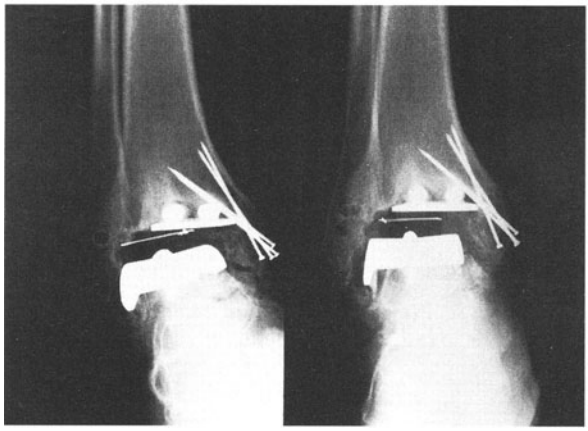


Fig. 4.2. Tilting of the meniscus at the 7 year follow-up (*left*). This happened after rupture of previously reconstructed lateral ligaments. Follow-up 1 year after ligament reconstruction (*right*)

The long-term follow-up of the series was used to detect whether certain diagnoses took a significantly different course than others.

4.3 Results

Table 4.1 shows the frequency of re-operations, change or arthrodesis compared with diagnosis. Fig. 4.3 shows the impact of certain diagnoses (now considered contraindications) on the survival rate. Table 4.2 shows the frequency of using the alignment technique, stabilization and the necessity for secondary sub-talar treatment.

Table 4.1. Failure rate according to diagnosis

OA 3/44:	6.8%
RA 2/22:	9.1%
Talus necrosis 4/4:	100%
Psoriasis arthr. 0/4*	
Previous fusion 1/1**	

* All four got severe heterotrophic bone formation stiffening the ankle joint.
** Painful calcification of the ligaments.

Table 4.2. Additional surgical procedures in 76 ankle arthroplasties

Alignment technique (>10° varus or valgus)	37/76
Lateral ligament reconstruction:	10/76
Sub-talar arthrodesis:	1/76

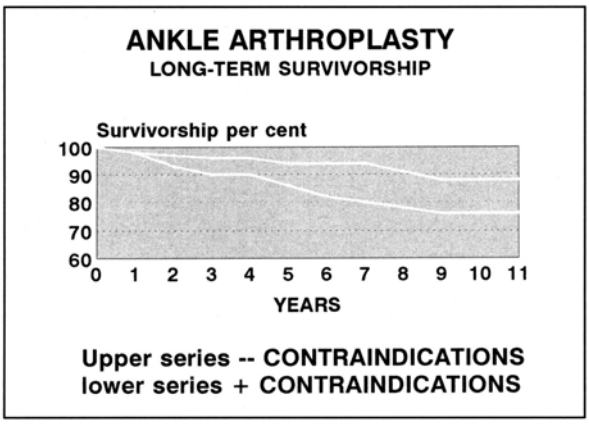


Fig. 4.3. Survivorship analysis of all cases (*lower curve*), and cases without contraindications (*upper curve*)

4.4 Discussion

The first-generation ankle prosthesis had many inborn errors. They were either too constrained to give stability or were spheroid in design. In the first case, all stresses were transferred to the bone-cement interface, leading to excessive loosening especially of the tibial components. In the second case, the arthroplasty would have to rely entirely on the ligaments, without any certainty of maintaining the ankle axis. Only a few of them confronted the problems from the malleolar-facet joints.

From the results of the present study, it became clear that talus necrosis, severe osteoporosis and psoriatic arthritis constitute the main contraindications. The real indications are primary or traumatic OA and forms of arthritis [rheumatoid, Lupus erythromatosis disseminatus (LED), hemachromatosis]. This is reflected not only in the prosthetic survival rate, but also in the clinical performance.

To obtain good and lasting results, alignment and stability are mandatory. The operative procedure and the prosthetic design offers the possibility of both. The gain in clinical mobility and function was significant and the pain relief has been excellent. Cases that have been aligned to the normal ankle axis, in general, hold their position.

The current results of this ankle arthroplasty used for the real indications are competitive with the best results of arthrodesis, and secondary sub-talar problems do not seem to occur.

References

1. Groth HE, Shen GS, Fagan PJ (1977) The Oregon ankle: a total ankle designed to replace all three articular surfaces. Orthop Trans 1:86
2. Wynn AH, Wilde AH (1992) Long-term follow-up of conaxial (Bech-Steefee) total ankle arthroplasty. Foot Ankle 13:303–306
3. Stauffer RN, Segal NM (1981) Total ankle arthroplasty: four years' experience. Clin Orthop 160:217–221
4. Newton E. St (1982) Total ankle arthroplasty. J Bone Joint Surg Am 64:104–111
5. Evanski PM, Waugh TR (1977) Management of arthritis of the ankle. Clin Orthop 122:110–115
6. Pipino F, Calderale PM (1976) An ankle joint prosthesis of new design. Il Policlinico 83:559–563
7. Pappas M, Buechel FF, DePalma AF (1976) Cylindrical ankle joint replacement. Clin Orthop 118:82–92
8. Kofoed H (1986) A new total ankle joint prosthesis. In: Kossowsky R, Kossovsky N (eds) Material sciences and implant orthopedic surgery. NATO ASI series E-116. Martinus Nijhoff, Dordrecht, pp 75–84

CHAPTER 5

Cemented and Uncemented Ankle Endoprosthesis: Clinical and Pedobarographic Results

K. Tillmann · M. Schirp · B. Schaar · B. Fink

5.1 Introduction

In case of failure of conservative treatment, painful ankle-joint destruction can be treated by either arthrodesis or arthroplasty. Our personal experience is almost exclusively limited to patients with rheumatoid arthritis (RA). Most of them are in a difficult situation due to disease with polyarticular affection. In approximately 40% of these patients, the ankle joint is affected; very frequently, bilaterally [9]. These patients will cope very badly with a bilateral arthrodesis. The necessary long-standing plaster fixation causes serious problems for them. Due to the bad quality of the frequently osteoporotic bone, the risk of non-union is greatly increased.

All of these considerations are arguments for the indication of endoprosthetic ankle replacement in spite of the inherent risks associated with any arthroplastic device.

5.2 Material and Methods

5.2.1 Cemented Prosthesis

In 1976, we started our studies with ankle arthroplasty, initially using the St. Georg endoprosthesis [1] – an uncemented single-axis metal – to polyethylene surface replacement; possibly the prototype for all later cemented designs. The disadvantage of the first generation of this prosthesis was the transfibular approach and the missing protection of the tibial component sideward tilting of the talus component, which sometimes caused painful impingement at either the tibial or the fibular side of the ankle joint.

After a brief attempt with the more-constrained, but also more bone-sacrificing, Oregonprosthesis [4], we favoured the slightly modified [7] Thompson-Parkridge-Richards (TPR) design which we used from 1977 to 1990. This was also a cemented and less-constrained single-axis metal against polyethylene prosthesis. This prosthesis was appreciated for: (1) the somewhat shal-

low side protection which was sufficient for our indications, (2) the anterior approach, (3) the rather limited bone resection, and (4) the shape of the talus component, which seemed to provide for slight rotation, abduction and adduction mobility during plantar flexion. From 1976 to 1995, we performed 67 cemented ankle prostheses with an average follow-up of 12.6 years.

5.2.2 Uncemented Prosthesis

In 1990, we started with the new concept of uncemented tri-component prosthesis. First, the New Jersey prosthesis (NJ) (DePuy Co.) [2], later, and partly parallel with it, the Scandinavian total ankle replacement (STAR) (Waldemar Link) [6] (33 NJ and 39 STAR). The average follow-up is 3.6 years.

We performed a clinical, radiological and pedobarographic control of the three types of endoprostheses we mainly used: TPR, NJ and STAR. Due to the very different follow-up times (TPR: 12.5 years, NJ: 3 years, STAR: 2 years), a valid comparison of the cemented versus the uncemented designs is not possible. Thus, only trends are given.

5.2.3 Pedobaric Measurements

The pedobarographic follow-ups were performed using the EMED-F-System. The stable measuring platform containing two sensors per square centimetre, with a resolution of 1 Newton, measuring 20 frames per second, was inserted in a walking course. A statistical analysis was performed using a multiple-variant analysis (Manova) and the Newman-Keuls test.

The results were compared with the measurements of a carefully selected control group of 35 "healthy" feet. In contrast to these "normal" measurements, the operated feet demonstrated a flattening of the two peaks caused by heel strike and push off in the maximum-force curves.

5.3 Results

The percentage of satisfied and very satisfied patients was equal for all three designs; more than 90%. More than 50% did not have any pain. The pain score (between none and slight pain, on average) improved with the time of follow-up – in contrast to the mobility. The range of motion, clinico-radiographically, amounted to 15–12° for the TPR, 28–22° for the NJ, and 35–25° for the STAR implants; this seems slightly better for the uncemented than the cemented implants, especially for the STAR.

The early and mid-term results rendered modest, but functionally valuable, mobility (and stability) and very good pain relief [8]. The rate of asep-

tic loosening that needed revision proved to be acceptable; 12% after 9 years on average. The much higher rate of radiolucent lines of a more- or less-extensive character (about 50% after 3.3 years of follow-up) did not lead to revision. This radiological phenomenon correlated with the follow-up time and with the postoperative range of motion [8].

In a more recent study, 41 patients with 55 joints have been included; 91% of living patients with functioning joints. Two of them have been unable to walk due to problems unrelated to the ankle joints. They were therefore lost to the pedobarographic follow-up. At the average follow-up of 12.6 years, 16 (23%) have been revised on account of aseptic loosening (19.5% with fusion and 4.5% changed to a NJ prosthesis).

Uncemented prostheses with an average follow-up of 3.6 years have given rise to two revisions (fusion) in one patient (talus osteonecrosis). Another joint was re-operated on because of heterotrophic bone formation.

In the pedobarographic analysis, comparisons were made toward the control group. The maximum forces under the mid-foot during walking considerably exceed the normal values for the TPR (185%), the STAR (210%) and the NJ (125%). The forces were markedly reduced under the heel. This amounted to a frequency of the normal load for the TPR (65%), the STAR (80%) and the NJ (70%). The maximum forces (pressures) were also reduced under the fore-foot, expressed as a percentage of the normal: the TPR 85%, the STAR 90% and the NJ 80%.

The uncemented prosthesis did not perform like the normal, but to a certain extent, did perform more physiologically than the cemented ones. When comparing the results, the STAR prosthesis came closer pedobarographically to that of normal feet than measurements of fused ankles [3]. We feel that a larger number of studies, especially controlled STAR prostheses, and a longer observation time is needed to reach valid conclusions.

5.4 Conclusions

Endoprosthetic replacement can be indicated in suitable cases as an alternative to ankle arthrodesis. This is especially true for the multiple joint handicapped RA patient. The postoperative treatment is less demanding and maintenance of their limited mobility is very much appreciated by the patients. Our preliminary results of the uncemented three-component designs, following the idea of Goodfellow's [5] meniscal knee endoprostheses, are very encouraging. We hope that some of the problems and risks of the cemented two-component prostheses can be solved by this new generation of ankle prostheses.

References

1. Buchholz HW, Engelbrecht E, Siegel A (1973) Totale Sprunggelenkendoprothese Modell "St. Georg". Chirurg 44:241–244
2. Buechel FF, Pappas MJ, Iorio LJ (1988) New Jersey low contact stress total ankle replacement. Biomechanical rationale and a review of 23 cementless cases. Foot Ankle 44:279–290
3. Dühr A (1995) Klinisch orthopädische und pedobarographische Untersuchung an Patienten mit chronischer Polyarthritis und Befall des Rückfußes prä- und postoperative. Dissertation, University of Hamburg, Germany
4. Groth H (1976) The Oregon ankle – a total ankle designed to replace all three articulation. In: Colloq. Interant: L'arthrose du cou-de-pied et du pied, Charleroi, Okt. Waft~ du cou-de-vied ct du pied. Charteroi Okt. (Editions du CIFo P Charicroi) pp 157
5. Goodfellow JW, O'Connor (1978) The mechanics of the knee and prosthesis design. J Bone Joint Surg Br 60:358
6. Kofoed H, Stürup J (1994) Comparison of ankle arthroplasty and arthrodesis. A prospective series with long term follow-up. The Foot 4:6
7. Pable JA (1987) Möglichkeiten und Komplikationen der operativen Behandlung am rheumatischen Fuß. Akt Rheumatol 12:25
8. Sinn W, Tillmann K (1986) Mittelfristige Ergebnisse der TPR-Sprunggelenkendoprothese. Akt Rheumatoi 11:231
9. Tillmann K (1979) The rheumatoid foot. Diagnosis, pathogenesis and treatment. Thieme, Stuttgart

Current Results of Ankle Arthroplasty

CHAPTER 6

The Low Contact Stress/Buechel-Pappas Total Ankle Prosthesis

H. C. Doets

6.1 Introduction

Ankle arthrodesis is considered to be the standard treatment for the severely affected ankle joint, although it is known to have certain disadvantages that compromise its outcome, including the risk of non-union (10–30%) and malunion. Furthermore, in longstanding rheumatoid arthritis, the hind foot is often stiff, either spontaneously or by surgery. In combination with a fused ankle joint, this inevitably leads to a disturbed gait pattern.

Total ankle prosthesis (TAP) has been reported as a procedure with a high rate of early aseptic loosening and inferior results compared with prosthetic replacement of other joints [1–4]. Hence, TAP is generally not seen as an acceptable alternative to arthrodesis. However, these results were all achieved using two-component designs of either a cylindrical or a spherical geometry, both having intrinsic constraints and not allowing an unrestricted motion.

The New Jersey low contact stress (LCS) TAP (DePuy, Warsaw, IN, USA), designed by Buechel and Pappas [5], uses a mobile polyethylene bearing between the metal tibial and talar components. This intercalated bearing gives this prosthesis totally unconstrained biomechanical characteristics. As the risk of a mechanical failure appeared to be diminished, and Buechel et al. reported good radiographic short-term results [5], it became acceptable for us, in 1988, to start using this prosthesis as an alternative to fusion.

6.2 Patients and Methods

Between 1988 and 1994, 30 TAPs were implanted in 28 patients (26 women and 2 men). Of these, 20 received the original LCS design and 10 received the slightly modified Buechel-Pappas design (Endotec, South Orange, NJ, USA), as the original LCS design was no longer available.

Diagnosis was rheumatoid arthritis, 25; juvenile chronic arthritis, 1; psoriatic arthritis, 1; and osteoarthrosis, 1. The average age at operation was 56 years (range 26–77 years). More than half had a stiff hind foot.

All prostheses were implanted through an anterior midline approach between the anterior tibial and extensor hallucis tendons. After preparation of tibia and talus, the talar and then the tibial component were implanted without the use of acrylic cement. Between these procedures, the polyethylene bearing was introduced by forceful distraction of the joint space. Routine wound closure with careful suturing of the extensor retinaculum finished the procedure.

Postoperatively, the ankle was immobilised in a below-knee walking cast for 6 weeks, with weight bearing to tolerance being allowed for. All patients were examined prospectively at yearly intervals. Clinical evaluation occurred by means of the LCS ankle score [5] [scale for pain, function, range of motion (ROM) and deformity to a maximum of 100 points] and by recording any complications.

Radiographic evaluation occurred by means of standardised antero-posterior (AP) and lateral X-rays of the ankle, on which the occurrence of radiolucencies and the position of the prosthetic components were assessed.

6.3 Results

At follow-up in 1997, one case was lost because the patient moved away 3.5 years after surgery.

6.3.1 Complications and Revisions

There was one deep, early infection that was successfully treated by lavage and parenteral antibiotics. Also, there were three delayed wound healings, for which a prolonged cast immobilisation was needed.

In five ankles, a preoperative fracture of a malleolus occurred. In three of these, there was normal healing and, in one, a stable non-union developed. A fifth case with a preoperative valgus deformity of 18° was complicated by a medial malleolar fracture, resulting in a painful non-union and persisting valgus deformity. Therefore, an arthrodesis had to be performed after 1.5 years.

There were a further three ankles that failed due to a varus instability with subluxation of the bearing. They all had the original LCS design and were early cases. In two of these, there was a preoperative varus deformity (18° and 12°, respectively), which could not be corrected during surgery and lead to failure after 7 years and 5 years. A third case with a well-aligned ankle, developed a varus instability after 6 years and was revised 8 years postoperatively.

All four failures were successfully converted to an arthrodesis.

6.3.2
Clinical Results

At follow-up, three patients with four TAPs had died of causes unrelated to the procedure 2–4 years postoperatively. These ankles had functioned well until the patients died.

At an average follow-up of 6 years (3–9 years), the remaining 21 TAPs were functioning well. The LCS ankle score improved from 40 (range 15–64), preoperatively, to 84 (range 63–96) at follow-up, due to a good pain reduction and a better walking capacity of the patients. The mobility of the ankle joint improved slightly from dorsiflexion to plantar flexion (DF-PF) of 2°–0°–23° to 6°–0°–25° at follow-up.

In two ankles, with pain due to talar-malleolar arthritis, debridement was performed with good final results.

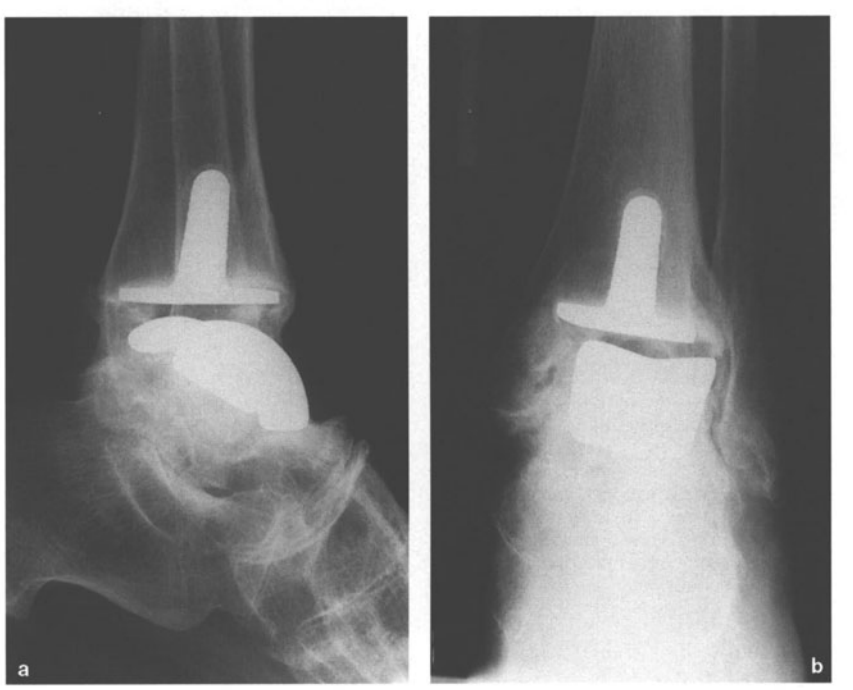


Fig. 6.1. First New Jersey low contact stress total ankle prosthesis (LCS TAP) implanted in September 1988: female 75 years of age; duration of rheumatoid arthritis 44 years at the time of operation; X-rays 9 years after implantation. Ankle score improved from 39° preoperatively to 87 at follow-up; range of motion from 0°–5°–20° to 0°–0°–30°

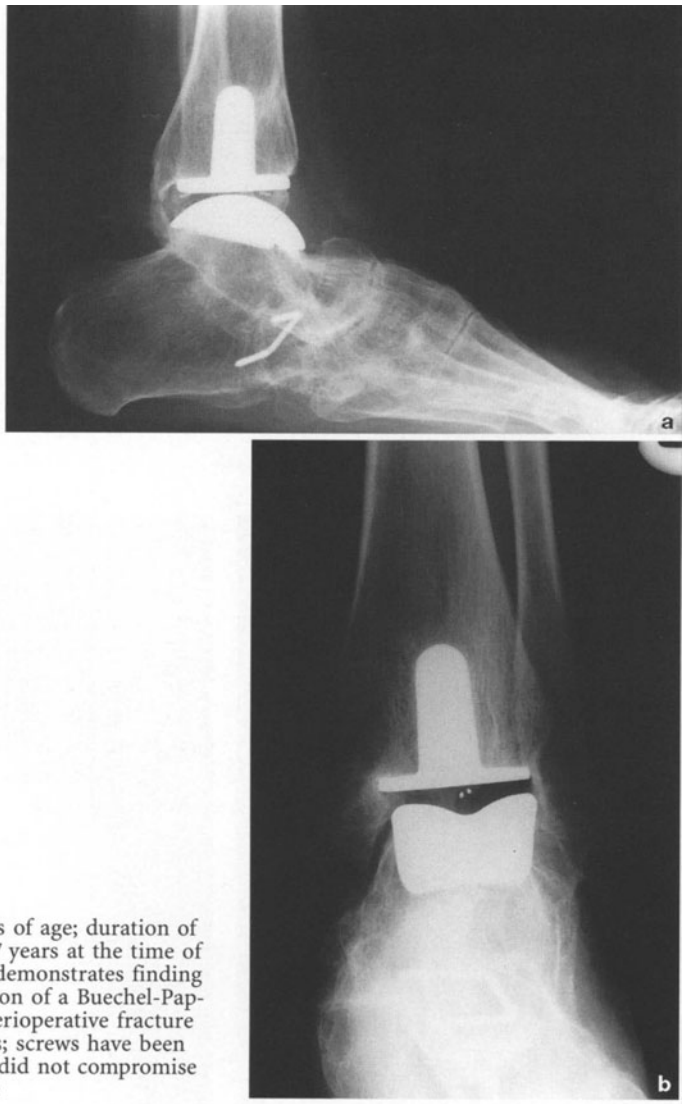


Fig. 6.2. Female 45 years of age; duration of rheumatoid arthritis 17 years at the time of operation. This figure demonstrates finding 3 years after implantation of a Buechel-Pappas prosthesis and a perioperative fracture of the medial malleolus; screws have been removed. The fracture did not compromise the good final outcome

6.3.3 Radiographic Results

There was only one asymptomatic loosening of the tibial component 5 years postoperatively, and there were no talar subsidences. Partial radiolucent lines occurred frequently around the stem of the tibial component, but were not progressive. Radiolucent lines around the talar component were seldom, incomplete and not progressive. Examples of radiographic results are shown in Fig. 6.1 and Fig. 6.2.

6.4 Discussion

Compared with two-component designs, the mobile bearing LCS/Buechel-Pappas TAP provides much better results, with a low incidence of mechanical loosening. However, preoperative deformity in the frontal plane is difficult to correct and, if persistent, will lead to instability and a subluxation of the bearing, necessitating conversion to an arthrodesis. This should be avoided by excluding varus or valgus deformity as an indication for TAP.

In our series, the procedure had a relatively high rate of malleolar fractures. This can partially be explained by the softer bone in these rheumatoid ankles, but should also be related to the forceful distraction needed for introduction of the bearing.

With the STAR (Waldemar Link, Germany), also a three-component resurfacing design, with a mobile polyethylene bearing, similar good results have been reported [6]. This demonstrates that in the ankle joint there is only place for a TAP, which uses a mobile bearing, and that the use of a two-component design is no longer indicated.

In conclusion, it is stated that the LCS/Buechel-Pappas TAP generally gives good clinical and radiographic results in rheumatoid arthritis if proper indications are applied. Apparently, varus or valgus deformity should be considered as a contraindication. This procedure can certainly be seen as an alternative to ankle arthrodesis, both in patients with rheumatoid arthritis and in those with osteoarthrosis living a sedentary life. Because of the technical difficulties that can be encountered during surgery and the low incidence of this procedure, implantation of a TAP must be restricted to the experienced ankle surgeon.

References

1. Hamblen DL (1985) Can the ankle joint be replaced? (editorial) J Bone Joint Surg Br 67:689–690
2. Bolton-Maggs BG, Sudlow RA, Freeman MAR (1985) Total ankle arthroplasty: a long-term review of the London Hospital experience. J Bone Joint Surg Br 67:785–790
3. Unger AS, Inglis AE, Mow CS, Figgie HE (1988) Total ankle arthroplasty in rheumatoid arthritis: a long-term follow-up study. Foot Ankle 8:173–179
4. Carlsson ÅS, Henricson A, Linder L, Nilsson J-Å, Redlund-Johnell I (1994) A survival analysis of 52 Bath & Wessex ankle replacements: a clinical and radiographic study in patients with rheumatoid arthritis and a critical review of the literature. Foot 4:34–40
5. Buechel FF, Pappas MJ, Iorio LJ (1988) New Jersey low contact stress total ankle replacement: biomechanical rationale and review of 23 cementless cases. Foot Ankle 8:279–290
6. Kofoed H, Danborg L (1995) Biological fixation of ankle arthroplasty: a sequential consecutive prospective clinico-radiographic series of 20 ankles with arthrosis followed for 1–4 years. Foot 5:27–31

CHAPTER 7

Total Ankle Replacement (LINK S.T.A.R.) for Rheumatoid Arthritis

P. L. R. Wood

7.1 Introduction

Rheumatoid arthritis is a chronic multi-system, polyarticular disease that eventually involves the ankle in 15–50% of patients. The severity of the disability in this group is perhaps most easily assessed by the number of other major joints that needed to be replaced for these patients prior to the ankle-joint replacement.

7.2 The Patients

There were 19 patients studied; 13 females and 6 males. Their average age was 61 years (range 33–74 years). Two patients required four major joint replacements, i.e. hip or knee; one patient, three replacements; five patients, two; and six patients, one.

All patients were treated for their painful ankle condition by means of an uncemented ankle arthroplasty (STAR, Waldemar Link, Germany). During the follow-up period, some patients underwent further major surgery to joints other than the ankle because of progression of the rheumatoid disease.

7.3 Operative Complications

Technical problems were encountered on two occasions early in the series. In one case, the distal-tibial cut was incorrectly carried out and a second operation was performed 2 weeks later when the problem was identified. This patient had an excellent result at 44 months. In another patient, the tibial component was not firmly seated in its bony bed. This was corrected the same day and she too has a good result.

Minor modifications to the instrumentation, but more importantly further surgical experience, has enabled the components to be satisfactorily inserted

since then. Wound healing was slow in three patients. There were no infections.

7.4 Results

7.4.1 Revisions

One patient gained only limited benefit from the procedure. He had a severe valgus deformity of the hind foot with the result that the insert tipped on the tibial component during weight bearing. Revision surgery has only partially corrected the problem. However, it has been 30 months since the revision surgery and the patient is now working and has less pain than prior to the ankle replacement.

7.4.2 Movement

The average range of movement post-operatively was 29° (range 15–35°). This movement took place entirely at the tibio-talar joint (the upper ankle joint) because each of these patients had marked stiffness of the hind foot. Three patients underwent a surgical hind-foot fusion prior to the ankle replacement. The average pre-operative range was 23° (0–50°). Twelve patients showed no alteration in the range of movement. Seven patients gained more than 10°. One patient lost movement (50° pre-operatively and 35° post-operatively).

7.4.3 Pain Relief

The primary indication for ankle joint replacement is pain relief, and the outcome in that respect has been entirely comparable with total-knee or total-hip replacement. All patients had less pain than before surgery. Fourteen patients had excellent pain relief with virtually no pain from the ankle joint. Satisfaction can be confirmed by the fact that three patients who developed symptoms in the opposite ankle later on, underwent replacement there as well.

7.4.4 Scoring in Rheumatoid Disease

Assessing the outcome of total joint replacement using functional scores is problematic when there are many joints involved in the disease process. For example, the ability to climb stairs may deteriorate during the follow-up per-

iod due to deterioration in the knee. It is the author's opinion that pain relief and survival of the prosthetic joint in the patient are the two most important measures. Maintenance of movement is also important.

7.4.5 Radiograms

The X-ray appearances were satisfactory in all cases with regard to the bone-prosthesis interface. Several X-rays showed radiating trabeculae from the tibial component, suggesting good fixation onto the tibia. The bone-prosthesis interface is hidden under the talar component, but to date no problems of subsidence or loosening have occurred. The polyethylene core was tipped on the tibial component in two cases, so that it is not in contact over the whole surface area. Experience suggests this occurs when there is severe pre-operative valgus deformity of the hind foot. It is now our practice to correct hind-foot deformity by triple arthrodesis prior to total ankle replacement.

7.5 Conclusion

The uncemented STAR three-component total ankle replacement offers the patient satisfactory function, with low post-operative morbidity and a low risk of complications. It provides excellent pain relief and, overall, at 3 years assessment, is "better" than open arthrodesis. This series describes early results and supports the belief that the long-term results will be satisfactory. The operation is technically difficult and requires a combination of experience with ankle surgery and the operative techniques of total joint replacement.

CHAPTER 8

Cementless Ankle Arthroplasty in the United States of America: The Alvine Agility Total Ankle Arthroplasty

S. T. HANSEN, JR.

8.1 Introduction

The Alvine agility total ankle arthroplasty was designed by Dr. Frank Alvine. It has been used for more than 12 years and has now been approved by the Food and Drug Administration (FDA) for use limited to six clinics. Dr. Alvine has been the instructor of this technique at these centers. The goals for the centers are to help refine the design of the implant and instruments and develop teaching centers for the technique. The purpose is to avoid excessive failure rates, which would reinforce old attitudes about ankle arthroplasty, and to ensure that the device can be as successful in the hands of others as it is in the hands of the developer.

In 1995, Dr. Alvine visited us in Seattle to discuss the preliminary results. He saw a large number of patients to help us define the indications. Eventually, he collaborated with us during our first six cases. This provided an excellent start.

8.2 The Prosthesis and Implantation Technique

The implant is a semi-constrained device (Agility, DePuy, USA). It permits 60° flexion/extension and axial rotation. It is made of chrome-cobalt alloy and has a polyethylene spacer. It is porous-coated for cementless use. The actual surgical technique includes alignment and distraction of the ankle joint by use of an external fixation device and fusion of the tibio-fibular syndesmosis via a lateral incision over the fibula. The hypothesis is that incorporating the tibio-fibular syndesmosis will provide adequate pain relief and ankle function.

8.3 Methods

Pain, activities, functional level and overall satisfaction were reviewed in a patients' questionnaire. The radiographic examination included component position, lucencies/lysis, syndesmosis fusion and adjacent-joint arthritis.

8.4 Patients

Follow-up time was a mean of 4.8 years. Two patients were deceased before their 2-year follow-up and 12 patients with 14 ankles were deceased at the time of review. Overall, 83 patients with 86 ankle implants answered the questionnaire. Radiograms of 93 cases were available and 54 patients with 56 ankle replacements were seen for clinical examination.

8.5 Results

Some degree of pain relief was experienced by 97% of the patients. Patients with post-traumatic arthrosis had more pain at follow-up than those with osteoarthritis and rheumatoid arthritis [1]. Pain was not associated with age, weight or time of follow-up. Our own preliminary results (Tables 8.1–8.4) seem to confirm the results obtained in the above-mentioned series.

Table 8.1. Pain and function. Results of a questionnaire for 86 ankles

Pain	
None	54%
Mild	29%
Moderate	16%
Severe	0%
Function	
Increase in function	72%
More comfortable walking with a heel	67%
Limp	10%
Regular use of cane	6%
Foot-ankle orthosis	4%

Table 8.2. Patients' satisfaction. There was no association between post-operative pain and plantar-flexion contracture

If needed the same operation again	95%
Recommend the operation to a friend	96%
Use no pain medication	81%

Table 8.3. Clinical range of motion (56 ankles)

Total range	36° (10–64)
Average plantar flexion contracture of 7°	50%

Table 8.4. Radiographic evaluation (93 cases)

Migration of tibial component	12
Delayed or non-union of syndesmosis	8

8.6 Discussion

The early clinical experience with the agility ankle is encouraging and appears to be superior to earlier ankle implants. Radiographs, obtained an average of 4.8 years post-operatively, showed better results with successful early fusion of the syndesmosis. We believe the results can be improved further by paying greater attention to alignment and by making some modifications to the design. There should be no malalignment in the leg itself. When a patient does not meet this criteria, alignment has to be undertaken concurrently with the ankle replacement; it may even be undertaken post-operatively. For example, we correct a malunited tibial fracture or a severe valgus foot prior to surgery on the ankle. We might correct tibia vara by means of a high tibial osteotomy or sub-talar arthrodesis for primary calcaneal vara or sub-talar arthrosis in varus or valgus, at the time of the arthroplasty. Alignment may seem satisfactory, pre-operatively, but the patient may stand with the heel too straight or in slight varus after insertion of an ankle prosthesis. In this case, the patient would return in 6 weeks or more after the ankle replacement, and the condition would be corrected at that time. A heel that is too straight or in varus produces a varus moment against the weak lateral ligaments, creating an unstable situation that could damage the bonding of the prosthesis. Hind-foot stability demands that the heel is in slight valgus while working against the very strong deltoid ligament. This can easily be recreated by a lateralizing calcaneal osteotomy.

Modifications of the prosthesis carried out thus far include making the surface area in the tibial component slightly larger, and increasing the available sizes of the prosthesis from three to six. More sizes will allow the surgeon to make maximal use of a patient's existing bone stock to make the device proportional to the patient's body weight. The malleoli, particularly the medial malleolus, must be left intact in order to maintain the integrity of the stabilizing ligaments. Stabilization of the mid-foot and forefoot to prevent forefoot-driven hind-foot valgus or varus will further improve results.

8.7 Conclusion

Our experience has been positive and we plan to continue using this device, as well as ankle arthroplasty in general, instead of arthrodesis in the majority of our patients with painful degenerated ankles.

References

1. Pyevitch MT, Saltzman CI, Callaghan JJ, Alvine FC (1997) Two to twelve year follow-up of a unique design (Agility). Presented at the Annual Meeting AAOS and AOFAS meeting, San Francisco

CHAPTER 9

Current Results of Ankle Arthroplasty – European Multi-Center Study of Cementless Ankle Arthroplasty

F. SCHERNBERG

9.1 Introduction

Ankle replacement is a controversial procedure (Hamblen 1985). Some authors state that it should never be performed, claiming that ankle arthrodesis is the gold standard when conservative treatment fails in cases of painful and degenerative ankles.

This dubious reputation is based on the initial experiences with rather poor devices. The first ankle prosthesis with modern material was introduced by Lord in 1970 (Lord and Marotte, 1980). It was derived from a stemmed hip prosthesis turned upside down. Progressively, devices adapted to the biomechanics of the ankle joint were used and provided better results. In a prospective series with long-term follow-up, Kofoed and Stürup (1994) demonstrated that ankle arthroplasty may be the treatment of choice for painful ankle joints.

Being aware of the limitations of ankle arthrodesis, we introduced the Scandinavian total ankle replacement (STAR) ankle arthroplasty in our practice and have been using it since 1992. Presently, we are pleased with this procedure and have the opportunity to refer here to the results of a 7-year multicentric study of cementless STAR ankle prosthesis used in six clinics in six European countries. The different clinics contributing to this study are:

- Denmark: Orthopaedic Clinic, Frederiksberg Hospital University of Copenhagen
- France: Orthopaedic Clinic, Hôpital Maison Blanche, C.H.U. de Reims
- Germany: Rheumaklinik Bad Bramstedt, University of Hamburg
- Italy: Instituto Ortopedico Galeazzi, University of Milan
- Sweden: Orthopaedic Clinic, Malmö, University Hospital, Malmö
- U.K.: Orthopaedic Clinic, Wrightington Hospital, Wigan

Table 9.1. Kofoed Ankle Score

	Points
Pain (maximally 50 points, exclusive points)	
No pain	50
Starting pain	40
Pain walking levels	35
Loading pain occasionally	35
Loading pain always	15
Pain during test or spontaneously	0
Function (maximally 30 points, NB: addition points)	
Toe walking	3
Heel walking	3
Normal cadence walking stairs	6
One-leg standing	6
No walking aids	6
No orthopaedic foot wear	6
Mobility (maximally 20 points, NB: addition points)	
Extension >10°: 5 P.	Flexion >30°: 5 P.
5–9: 3 P.	15–29: 3 P.
<5: 1 P.	<15: 1 P.
Supination >30°: 3 P.	Pronation >20°: 3 P.
15–29: 2 P.	10–19: 2 P.
<15: 1 P.	<10: 1 P.
Valgus during loading	Varus during loading
<5°: 2 P.	<3°: 2 P.
5–10: 1 P.	4–7: 1 P.
>10: 0 P.	>7: 0 P.

Result evaluation: 85–100 points: *excellent*; 75–84 points: *good*; 70–74 points: *fair*; <70 points: *not acceptable*.

9.2 Materials and Methods

Patients and lesions: from 1990 to 1996, ankle replacement was performed with the non-cemented STAR device (Waldemar Link, Germany) in 131 painful ankle joints, where conservative treatment had failed. Of these, 68 ankles had rheumatoid arthritis and 63 had osteoarthritis.

9.2.1 Patient Evaluation

The ankle joint status was assessed according to the Ankle score system (Kofoed 1986) (Table 9.1).

9.2.2 The Ankle Prosthesis

The STAR ankle prosthesis consisted of a three-component device. Both the tibial flat plate with two dorsal cylindrical bars and the talar cap-imitating component were coated with hydroxy-apatite. Between these two components, a gliding polyethylene meniscus with a height ranging from 6 to 10 mm was inserted.

9.2.3 The Surgical Procedure

The surgical procedure was performed in a bloodless field using spinal or epidural analgesia. The ankle joint was approached via a slightly curved anterior incision from about 10 cm above the ankle joint to 8 cm below it.

The resection of the tibia was cut tangentially to the long axis of the tibia just touching the inner arc of the distal tibial excavation. The talus resection removed approximately the upper 4 mm of the talar dome, while holding the hind foot in neutral position. The medial and lateral talar articular surfaces were removed to a depth of 2 mm maximum, allowing space for the thickness of the talar cap prosthesis. Ligaments and vessels were preserved.

After preparation of the bone structures, the hydroxy-apatite-coated prosthetic parts were inserted and gently punched into the subchondral bone beds. Trial menisci were inserted to find the best stability.

9.2.4 Post-operative Care

Post-operatively, the patients wore a walking plaster with the foot in neutral position for 4 weeks, allowing full weight bearing. After removal of the plaster, normal walking, squatting and toe-standing was initiated.

9.2.5 The Follow-Up

The patients were seen the first year after 3 and 6 months and every year thereafter for clinico-radiographic follow-up.

9.3 Results

In this series of 131 ankle replacements with a minimum of 1-year follow-up, failures occurred within the first 2 years of use. Of 131 cases followed-up in

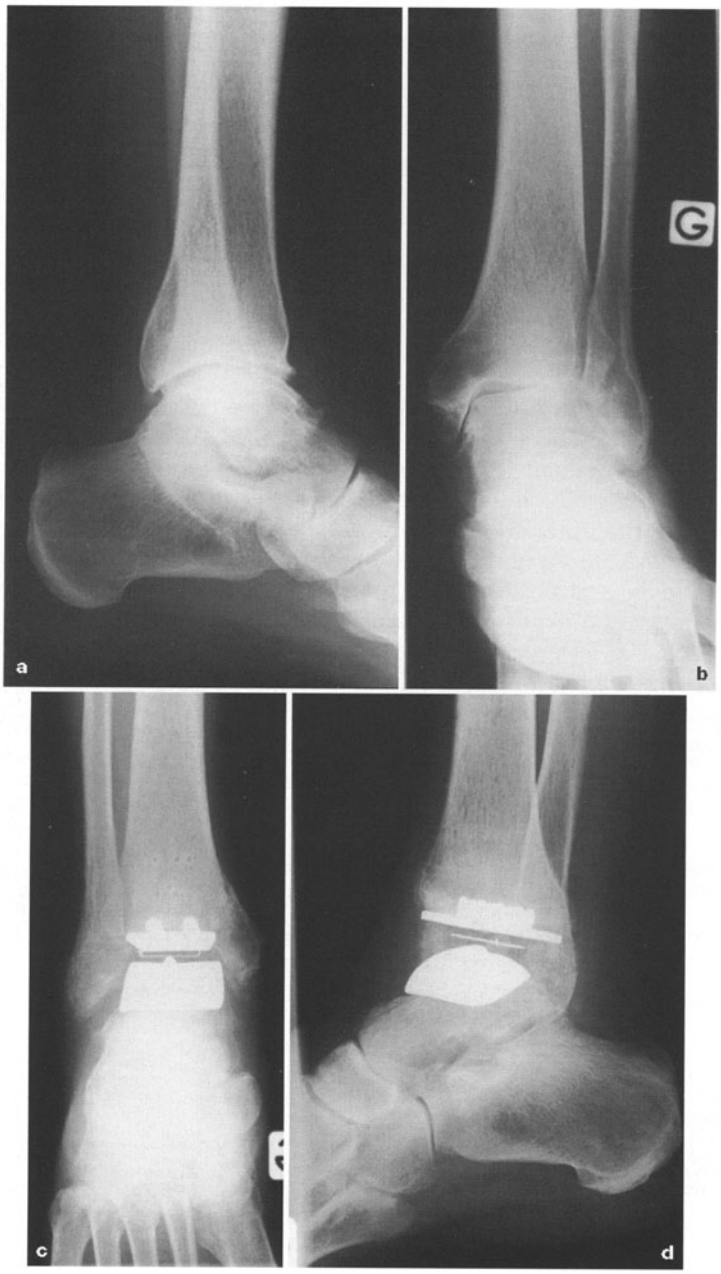


Fig. 9.1 a–d. A 69-year-old man with osteoarthritis resulting from post-traumatic lateral instability in the left ankle. **a** Pre-operative views. **b** 2-year post-operative views

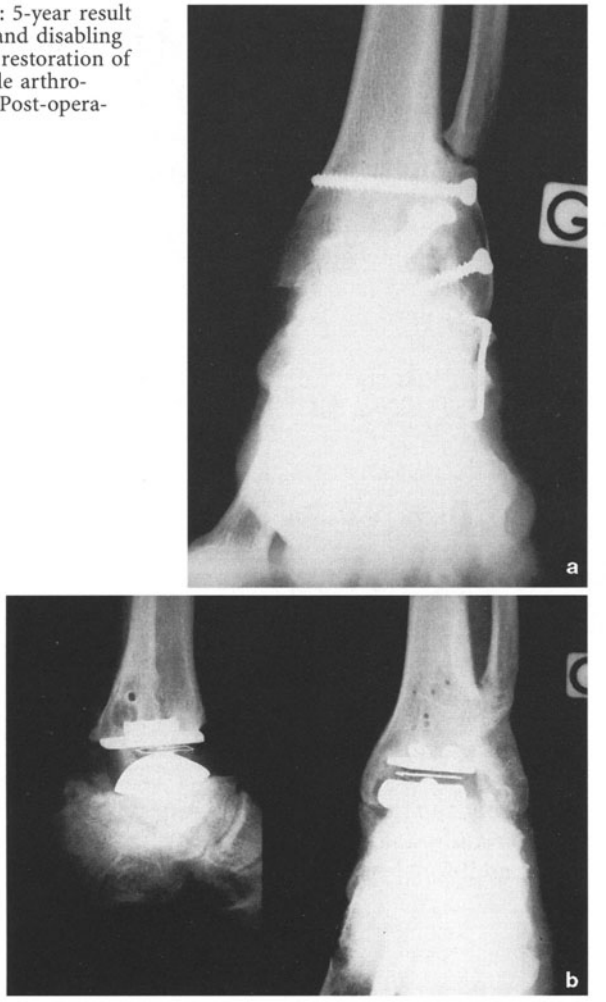


Fig. 9.2 a, b. A 34-year-old man: 5-year result after a pilon fracture. Painful and disabling ankle fusion. Actual situation: restoration of ankle mobility with STAR ankle arthroplasty. **a** Pre-operative view. **b** Post-operative view

Table 9.2. Follow-up of material. Demonstration of early failures with a new prosthesis

Cases	Number	Fusion	Revision
1-year	131	3	5
2-year	71	1	4
3-year	42	–	–
4-year	17	–	–
5-year	12	–	–
6-year	10	–	–
7-year	5	–	–

a minimum of 1 year, there is evidence of eight failures. Of these eight cases, an ankle joint arthrodesis was performed in three of these and a revision in the five remaining. Of 71 patients with a minimum follow-up of 2 years, there is evidence of five failures. Of these five cases, an ankle joint arthrodesis was performed in one and a revision in the four remaining. With a follow-up of more than 2 years, there is no evidence of failure (Table 9.2).

The analysis of the Kofoed Ankle Score (KAS) shows that, during the first 2 years, the score is within 80 points. After 2 years, the score increased up from 1 to 5 points reaching 85 points (+/– one point) and then remained stable. The failure rate was eight out of 131 (6.1%) during the first year and five out of 71 (7%) during the second year. For the remaining 5 years no failures occurred.

The calculated survival rate dropped from 93.9% during the first year to 87.3% during the second, but remained unchanged up to the seventh year.

9.4 Discussion

Based on the results of this study, uncemented ankle STAR prosthesis appears to be a reliable arthroplasty in cases of either rheumatoid arthritis or osteoarthritis (Fig. 9.1).

In this case, the main complication occurred during the first 2 years, reflecting the troubles associated with a new procedure. Once the learning curve was over, the results stayed constant. This is illustrated both in the survivorship analysis and in the range of scorings. In addition, no failure resulted from the device itself. The good results depended on a careful patient selection and good technical management of the procedure. Our next goal is to find additional reliable indications (Fig. 9.2).

References

Hamblen DL (1985) Can the ankle joint be replaced? (editorial) J Bone Joint Surg Br 67:689–690

Kofoed H (1986) A new total ankle joint prosthesis. In: Kossowsky R, Kossovsky N (eds) Material sciences and implant orthopedic surgery. NATO ASI series E-116. Martinus Nijhoff, Dordrecht, pp 75–84

Kofoed H, Stürup J (1994) Comparison of ankle arthroplasty and arthrodesis. Prospective series with long term follow-up. The Foot 4:6–9

Lord G, Marotte JH (1980) Arthroplastie totale de cheville. Expérience sur 10 ans. A propos de 25 observations personnelles. Revue de Chirurgie Orthopedique.66:527–530

CHAPTER 10

Comparison of Cemented and Cementless Ankle Arthroplasty

H. KOFOED

10.1 Introduction

Cementless ankle arthroplasty has been used within the last decade. There are no reports to say whether this procedure would give better results than prosthesis fixed with cement. It has been claimed that cementless use of prosthesis would not change their fate [1]. While waiting for the Scandinavian total ankle replacement (STAR) prosthesis to become cementless (hydroxy-apatite coated), it was first used with cement fixation, from 1986 to 1989. Since 1990, the prosthesis has been used in the cementless version. All patients are in a prospective series with yearly follow-ups. This gives an opportunity to test whether the cementless fixation gives better results or not.

10.2 Material and Methods

From 1986 to 1989, 36 cases were treated with a meniscal-bearing non-constrained ankle arthroplasty (STAR, Waldemar Link, Germany). From 1990 to 1996, 40 cases were treated with the cementless version of the same prosthesis (hydroxy-apatite coated). The cases were followed up every year. The collection of results from the cases performed from 1986 to 1989 were followed through 1992, i.e. a maximum of 7 years. A collection of results from the cementless group was stopped in 1996, i.e., also a maximum of 7 years follow-up. Survival analysis was performed on this basis. The operative technique did not change throughout the period except for the method of fixation. The postoperative regime was slightly different. The group of cemented arthroplasties wore a walking cast for 14 days postoperatively, whereas the cementless group used a walking cast for 4 weeks (osteoarthritis) or 6 weeks (rheumatoid arthritis). Provided a supplementary ligamentous reconstruction was performed, a walking cast was worn for 6 weeks (both groups). The Kofoed ankle score (KAS) [2] was used for clinical evaluation.

10.3 Results

The cemented group consisted of 36 prostheses. The median age of the patients was 57 years (range 32–83 years). There were 40 prostheses in the cementless group. The median age of the patients at the time of operation was 56 years (range 29–79 years). There was no significant age difference between the two groups.

The preoperative total score in the cemented group was 29 points (range 7–47) and 32 points (range 6–49) in the cementless group: n.s. The diagnosis did not have the same distribution. The arthritis/arthrosis distribution ratio in the cemented cases was 19/17. The arthritis/arthrosis distribution ratio in cementless cases was 9/31. The latest median score in the cemented group was 82 points and in the cementless group 92 points, $P<0.05$. The survival curves for cemented and cementless prosthesis are shown in Fig. 10.1.

10.4 Discussion

Hamblen [1] stated in 1985 in an editorial that cementless use of ankle arthroplasty would probably not change its outcome. The results of the present study seem to show that significantly better results can be expected from cementless fixation of ankle prosthesis. There could be several reasons for this. First, the cementing technique in the ankle is more difficult than that of the other weight bearing joints. Pressurization of the cement up into the tibia is nearly impossible considering the anatomic features. This could explain why tibial-component failure is the most frequent failure mode. Second, cement could intrude into the back of the joint and cause interference with mobility

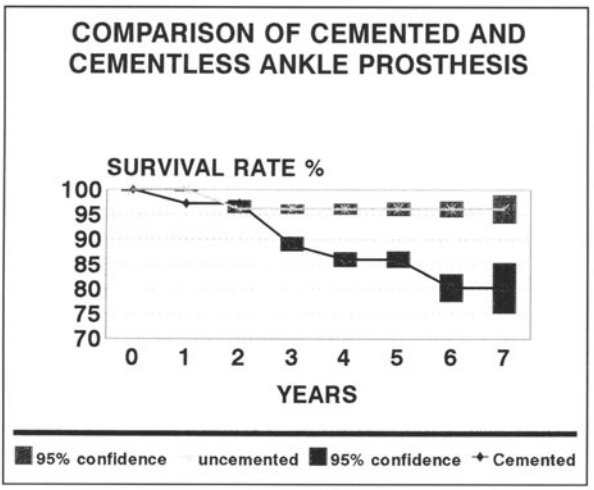


Fig. 10.1. Survival curves for cemented and cementless prosthesis

and, if it became loose, it could even cause wear in the artificial joint. Third, only the most distal 1–1.5 cm of the tibia is suited for cementation. Above that level, there is only fatty marrow. Using a technique where the talus component is cemented on top of the talus dome must lead to cementing of the tibial component in the bone marrow. This is bound to cause a risk of loosening of the tibial component.

Although the normal axis of rotation was kept with use of the STAR prosthesis and cement was only inserted in the solid subchondral bone of the distal tibia, the frequency of revision or arthrodesis in cemented cases was significantly higher than that of cementless prosthesis. These results speak very much in favour of cementless prosthesis in the ankle.

References

1. Hamblen DL (1985) Can the ankle joint be replaced? (editorial) J Bone Joint Surg Br 67:689–690
2. Kofoed H (1995) Cylindrical cemented ankle arthroplasty. Foot Ankle Int 16:474–479

CHAPTER 11

Revision of Different Ankle Prostheses

Å. S. Carlsson

11.1 Introduction

Any surgeon performing total ankle replacements will sooner or later have to deal with a variety of complications. It may be wound-healing problems, impingement, malpositioning of the components, deep infection or aseptic loosening. Arthrodesis is the most common method used to handle the three latter complications. However, in some aseptic failures, exchange of one or both components has been attempted, but only 15 cases have been documented in the literature (Stauffer 1982; Groth and Fitch 1987; Makwana et al. 1995). The following chapter is a report of my personal experiences of 15 such cases.

11.2 Material

A total of 119 total ankle prostheses were implanted in Malmö University Hospital between 1974 and 1996. Of these, 95 were due to rheumatoid or psoriatic arthritis and 24 were due to osteoarthritis, mainly as a consequence of trauma. In addition, 68 were the cemented St. Georg, Imperial College London Hospital (ICLH) and Bath & Wessex designs, whereas the remaining 51 were either custom made, New Jersey or Scandinavian total ankle replacement (STAR) prostheses.

In 21 cases, arthrodesis has been performed due to aseptic and septic complications, and these have been presented elsewhere (Carlsson et al. 1998).

In 15 cases, at least one of the components has been exchanged due to malpositioning or aseptic failure. The original diagnosis was rheumatoid arthritis in ten cases, psoriatic arthritis in one and osteoarthritis in four.

11.3 Results

For further details regarding the cases described below, refer to Table 11.1.

11.3.1 Case Numbers 1–5

Five females with rheumatoid arthritis (RA), operated on with cemented total ankle arthroplasties between 1982 and 1985, were revised after 2–7 years. In all cases, the talar component had subsided and in four, the tibial component was either loose or surrounded by a wide radiolucent zone. In four cases, both components and in one, only the talar component were exchanged using cemented Bath & Wessex components. No further ankle surgery was undertaken in these five patients. After 5–7 years following revision, three ankles were radiographically intact, whereas subsidence of the new talar component had occurred in two cases.

11.3.2 Case Numbers 6–8

Three ankle prostheses of a custom-made osseointegrated design implanted in three patients due to posttraumatic osteoarthritis, RA and psoriatic arthritis, have been revised with exchange of the tibial component only. The integrated talar component, with a ball corresponding to the talar component of the Bath & Wessex prosthesis, was well fixed and left in place in all three cases. The loose tibial component was removed, and, after transplantation of morcellized allograft, a new tibial component of the Bath & Wessex design was cemented onto the graft in two of these cases. In the third case, a stemmed component, as described in Case no. 9 (Fig. 11.1 C, D), was inserted without bone cement and a custom-made polyethylene meniscus was inserted between the metallic parts. After 4 years, 4 years and 1 year, respectively, no change in the position of the new tibial components was observed. Two of the three patients were painless. The case with post-traumatic osteoarthritis still suffered from starting pain. The reason for this is presumed to be impingement, and the patient was offered debridement in order to create more space around the malleoli.

11.3.3 Case Numbers 9–14

In these six cases, the tibial component of the STAR ankle was either too short, malpositioned or it became loose for unknown reasons. Revision was

Table 11.1. Results for case numbers 1–15

Patient	Gender and age at index surgery	Diagnosis	Year of index surgery	Prosthesis	Year of revision	Components exchanged	Bone graft	Follow-up (years)	Radiography	Clinical results
1	F61	RA	1982	ICLH	1984	Both [a]	No	7	Intact	Painless
2	F51	RA	1987	B & W	1991	Both [a]	No	5	Intact	Painless
3	F43	RA	1984	B & W	1991	Talar [a]	No	5	Subsidence (talus)	Moderate pain
4	F45	RA	1985	B & W	1989	Both [a]	No	7	Intact	Painless
5	F44	RA	1990	B & W	1989	Both [a]	No	6	Loose (both)	Severe pain
6	M59	OA	1992	Custom	1993	Tibial [a]	Allo-	4	Intact	Starting pain
7	F54	RA	1993	Custom	1993	Tibial [a]	Allo-	4	Intact	Painless
8	F64	PSA	1993	Custom	1996	Tibial	Allo-	1	Intact	Painless
9	M72	RA	1993	STAR	1996	Tibial	Allo-	1	Intact	Painless
10	M70	OA	1993	STAR [a]	1994+1996	Tibial	Allo-	3	Subsidence (talar)	Moderate pain
11	M69	RA	1994	STAR [a]	1995	Tibial	Auto-	1	Intact	Painless
12	F66	OA	1994	STAR	1996	Tibial	Auto-	1	Talar tilt	Slight pain
13	F70	OA	1994	STAR [a]	1994	Tibial	Auto-	3	Intact	Moderate pain
14	F26	RA	1996	STAR	1996	Tibial	Auto-	1	Intact	Painless
15	F69	RA	1994	STAR	1994	Tibial [a]	No	–	Arthrodesis 1996	Arthrodesis 1996

RA rheumatoid arthritis; *OA* Osteoarthritis; *PSA* Psoriatic arthritis.
[a] Use of bone cement.

undertaken using a stemmed component, either belonging to the New Jersey design or produced by the Link company for use in revision situations. The intact-talar component was left in place in all six cases. These stemmed components are both blasted with and without hydroxy-apatite coatings. They were implanted without the use of bone cement and placed on a bed of cancellous autograft or morcellized allograft. In one case (no. 14), a support consisting of cortical bone obtained from the iliac crest was also placed anteriorly.

11.3.4 Case Number 9

This prosthesis was implanted in 1993 in a 72-year-old man with RA. For unclear reasons only the smallest, i.e., the 30-mm-long tibial component, was available at that time. In spite of insufficient posterior support, the prosthesis worked for 3 years, during which time the patient was painless. After this, the period pain recurred and the tibial component tilted. It was replaced by an uncemented-stemmed Link component and the patient is again painless and has a good function (Fig. 11.1 A–D).

11.3.5 Case Number 10

This patient was a 70-year-old man with both hips, both knees and one ankle replaced because of osteoarthritis. The opposite replaced ankle was revised at 6 months because of varus malpositioning of the tibial component and pain. A new hydroxy-apatite (HA)-coated standard component was inserted in neutral position and fixed with cement. However, progressing radiolucencies very soon appeared and the tibial component was again revised; this time with a stemmed component (New Jersey) inserted into morcellized allograft without the use of bone cement. This component was, after 3 years, radiographically stable and without surrounding lucencies. Unfortunately, the original talar component has subsided after the second revision of the tibial component, but presently no further surgery is planned.

11.3.6 Case Number 11

This patient was a 69-year-old man with RA. One ankle was replaced in 1994. The tibial component was implanted correctly and with good bone support. However, it was cemented. After less than 2 years it was loose and therefore exchanged using a stemmed-Link component. The patient has since been painless and with a good function.

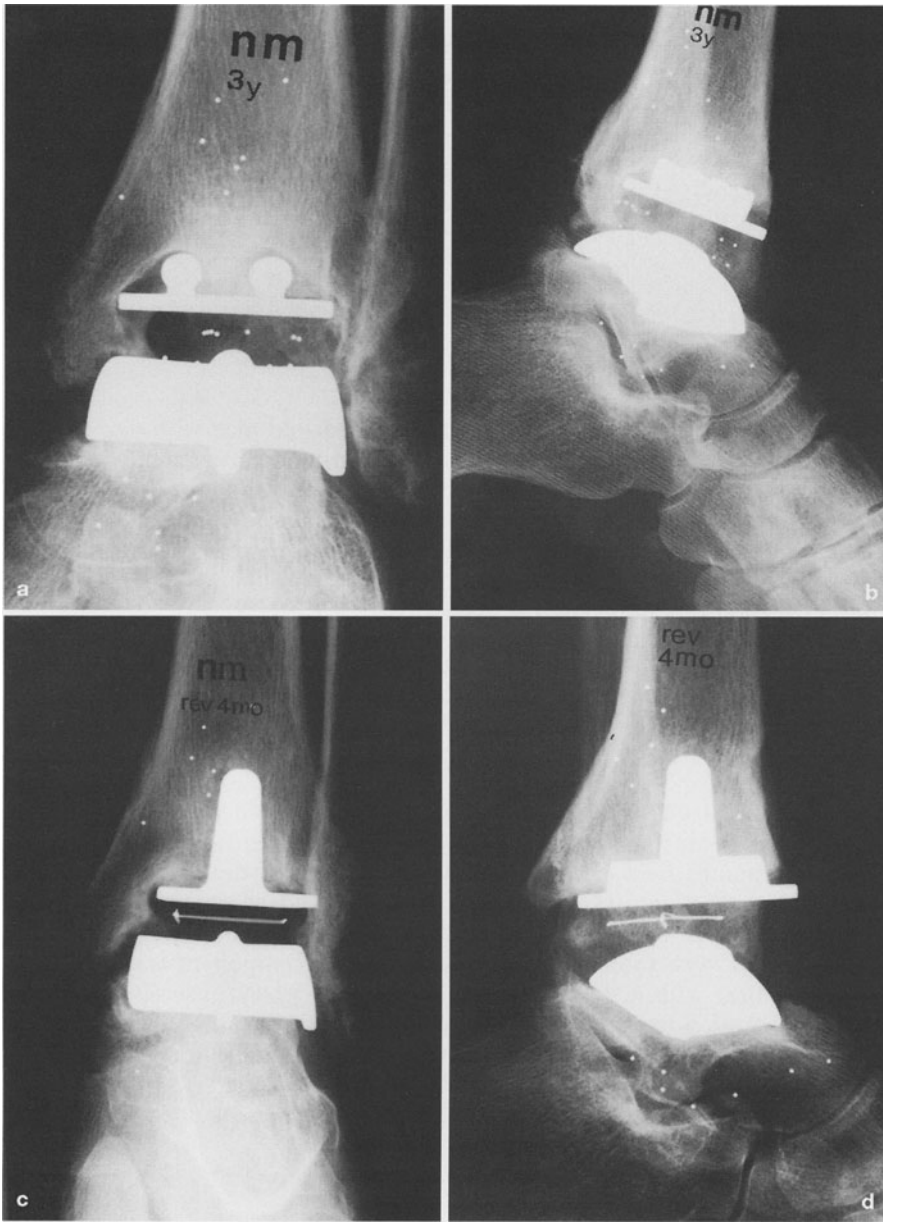


Fig. 11.1a–d. Patient number 9. **a**, **b** 3 years after implantation of a STAR prosthesis. **c**, **d** 4 months after exchange of the tibial component

11.3.7
Case Number 12

The next patient was a 66-year-old farmer's wife with bilateral-primary osteoarthritis. One ankle was replaced in 1993 and is still intact with good function. The second ankle was replaced in 1994, unfortunately with the tibial component inserted too laterally, engaging into the fibula. The patient never became completely painless and, radiographically, the talar component began to tilt into varus. It was replaced by an uncemented stemmed-Link component after 2 years. After tibial revision, the talar component tilted somewhat forwards. The patient's complaints are moderate and presently no further surgery is planned.

11.3.8
Case Number 13

This patient is a 70-year-old woman with primary osteoarthritis. Her ankle was replaced in 1994. The HA-coated tibial component was fixed with bone cement in slight valgus position. The patient was never satisfied with her ankle and after only 1 year, a wide radiolucent zone was observed above the tibial component, apparently indicating that it had become loose. This was confirmed at the revision when it was changed to a stemmed-New Jersey component.

11.3.9
Case Number 14

This patient was a 26-year-old woman with severe RA and long-standing ankle pain. Prior to surgery, she sustained a stress fracture of the fibula at the level of the ankle joint. Unfortunately, the angulation was not corrected at the time of ankle replacement in 1996. Instability ensued and, presumably for that reason, the tibial component tilted. It was revised after only 6 months using a graft from the iliac crest for anterior support. The fibula was also osteotomized and fixed with a plate. She is now painless with good function of her ankle.

11.3.10
Case Number 15

This patient was a 69-year-old woman with RA. Both ankles were replaced in 1994 by means of STAR prostheses. On one side, the radiographs showed that the tibial component had an unacceptable malposition. This was revised after only 3 weeks, when a new HA-coated standard-tibial component was

implanted in a correct position and fixed with bone cement. This procedure did not make the patient pain free and wide radiolucencies developed. In 1996 the ankle was fused.

11.4 Discussion

If an ankle replacement fails, it may be tempting to fuse the joint. This approach is recommended if there is a deep infection or the range of motion is very restricted. However, if infection seems unlikely and the range of motion exceeds about 30°, exchange of one or more components should be considered. The indication for an exchange operation is, in my view, strengthened if all joints distal of the ankle are already stiff or fused.

Three of five patients with an exchanged ICLH or Bath & Wessex ankle were painless the last 5–7 years after revision, and their prostheses were radiographically intact. In the five RA cases previously described in the literature, the prosthesis again loosened (Groth and Fitch 1987; Makwana et al. 1995).

Impaction grafting has not previously been described in revision ankle arthroplasty. This technique was used in nine cases. Until now, only one of these components has tilted slightly. However, after revision of the tibial component, two of the original talar components have tilted.

The conclusions below from my 15 cases should be interpreted with caution.

1. The tibial component should be supported both anteriorly and posteriorly by cortical bone.
2. Do not anchor a hydroxy-apatite-coated implant by bone cement. Four such cemented tibial components had to be revised.
3. In case of revision, bone grafting of defects is advised instead of excessive bone resection. Morcellized allograft or autograft can be used.
4. A stemmed tibial component with a blasted undersurface, but without HA coating, introduced through an anteriorly placed cortical window, seems suitable for revision of, for example, the STAR prosthesis.

References

Carlsson ÅS, Montgomery F, Besjakov J (1998) Arthrodesis of the ankle secondary to replacement. Foot Ankle Int (in press)

Groth HE, Fitch HF (1987) Salvage procedures for complications of total ankle arthroplasty. Clin Orthop 224:244–250

Makwana NK, Morrison P, Jones CB, Kirkup J (1995) Salvage operations after failed total ankle replacement. Foot 5:180–184

Stauffer RN (1982) Salvage of painful total ankle arthroplasty. Clin Orthop 170:184–188

Laboratory Investigations

CHAPTER 12

The Fibula Rotates During Motion in the Ankle Joint

J. Helweg · H. Kofoed

12.1 Introduction

The surfaces of the ankle joint are intended to stay congruent during the arc of motion. This phenomenon is still a matter of debate, especially concerning the shape of the upper joint surface of the talus, which is wider anteriorly than posteriorly. The upper joint surface is probably close to the part of a cone with the largest radius laterally [1]. Several theories and experiments have tried to explain the motion of the fibula during the arc of motion in the ankle joint. The different theories are summarized in Table 12.1. There are still disagreements as to whether the fibula rotates along its axis during plantar to dorsal flexion in the ankle joint. The purpose of the present study was to investigate the possible rotational motion of the fibula during ankle movement.

Table 12.1. Theories of fibular motion during the arc of ankle motion

Theory	Author	Year	Reference
Lateral translation (widening of the mortise)	Ashhurst and Bromer	1922	[2]
	Grath	1950	[3]
	Inman	1960	[1]
	Kärrholm et al.	1976	[4]
	Ahl et al.	1985	[5]
	Lundberg	1989	[6]
Antero posterot translation	Alldredge	1973	[7]
	Lundberg	1989	[6]
Rotation about longitudinal axis	Close	1956	[8]
	Lederman & Cordey	1984	[9]
Cranio caudal translation	Weinert et al.	1973	[10]
	Cedell	1975	[11]
	Scranton et al.	1976	[12]
	Reimann et al.	1986	[13]

12.2 Materials and Methods

We have assessed the rotation of the fibula around its longitudinal axis during unloaded passive plantar to dorsal flexion in the ankle joints of 14 feet with intact ankle joints in eight fresh cadavers. Their median age was 69 years (range 54–87 years). Ten of the feet were from males, the rest from females.

A stereo-video photogrammetric system, commercially available (McReflex, Qulisys), was used for the investigations. This system basically consists of two video-cameras, each linked to a video processor that calculates and reduces the input data. Inputs are white reflections on a dark background from infrared-illuminated ball markers. The reduced data are the 2-D coordinates of the location of the centers of the markers. These coordinates and the size of the marker are sent to the computer which combines the data from the different processors to 3-D coordinates for each marker – 50 times per second.

The computer programs are able to calculate angles, distances, velocities and accelerations from the data. According to our own investigations, the accuracy of the measurements was considered to be 0.1° in the present setup.

Two reflective-ball markers were threaded on each of three stainless-steel pins, with approximately 10 cm between them. Two of the pins were screwed percutaneously into the tibia and the fibula, respectively, in such a way that they were placed in the same plane, and the one marker was close to the skin. The third pin was placed through the collum of the talus in front of the foot in the same plane as the pin in the tibia. Finally, a steel pin with a single marker was placed proximally on the tibia, in the plane of the tibia and the talus markers (Fig. 12.1).

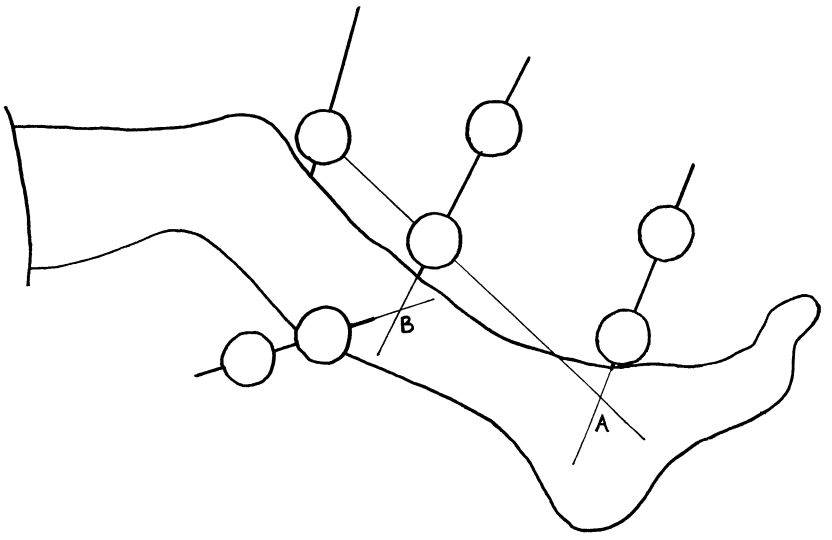


Fig. 12.1. Placement of the steel pins with the ball markers and the angles measured

While the cameras were running, an assistant moved the ankle joint from maximal plantar to maximal dorsal flexion four to five times over a period of 15 seconds. The angles between the pins in the tibia and the talus (A) and the pins in the tibia and the fibula (B) were calculated continuously throughout recording by the computer program.

12.3 Results

In all of the fourteen ankles, an outward rotation of the fibula was demonstrated during the movement from plantar to dorsal flexion in the ankle joint. The shape of the curves was essentially the same in the cases shown in the example in Fig. 12.2.

The results are shown in Table 12.2. No correlation between the degree of ankle flexion and the degree of the fibula rotation could be found (correlation coefficient 0.4).

12.4 Discussion

The relationship between the fibula, the talus and the tibia during motion of the ankle joint is certainly not as simple as may be assumed.

In our series, the fibula showed rotational motion in all cases. The rotation demonstrated is small, but consistent, at least when the ankle is unloaded in vitro. Other authors have found a rotational motion of the fibula, although the findings by some have been considered to be either inconsistent or of an insignificant magnitude [5, 6, 8, 9].

A horizontal rotation of up to about 10° in the talo-crural joint during plantar to dorsal flexion in the ankle joint have been demonstrated [6, 8, 14].The significance of this phenomenon in relation to the fibula is interesting. Is there an interaction by law between the bound rotation of the tibia against the talus and the motion of the fibula? No such law of interaction has, to our knowledge, yet been found [1].

A widening of the ankle mortise ranging from 0 to 2 mm has been demonstrated by many authors (Table 12.1). This widening is less than should be expected, considering the upper joint surface of the Trochlea, which has been measured from 0 to 6 mm wider anteriorly than posteriorly [1]. Inman explained this by his theory of the upper surface of the Trochlea joint surface being, more likely, a part of a cone, with the axes converging medially, rather than a simple cylinder [1].

A rotational motion of the fibula may add to the explanation of the joint congruity, by opening up the mortise during dorsiflexion of the ankle joint and, in this way, being responsible for the widening of the mortise. The motion of the fibula is most likely a combination of several translations and rotation, which has to be assessed, preferably all together, in vivo also during loading.

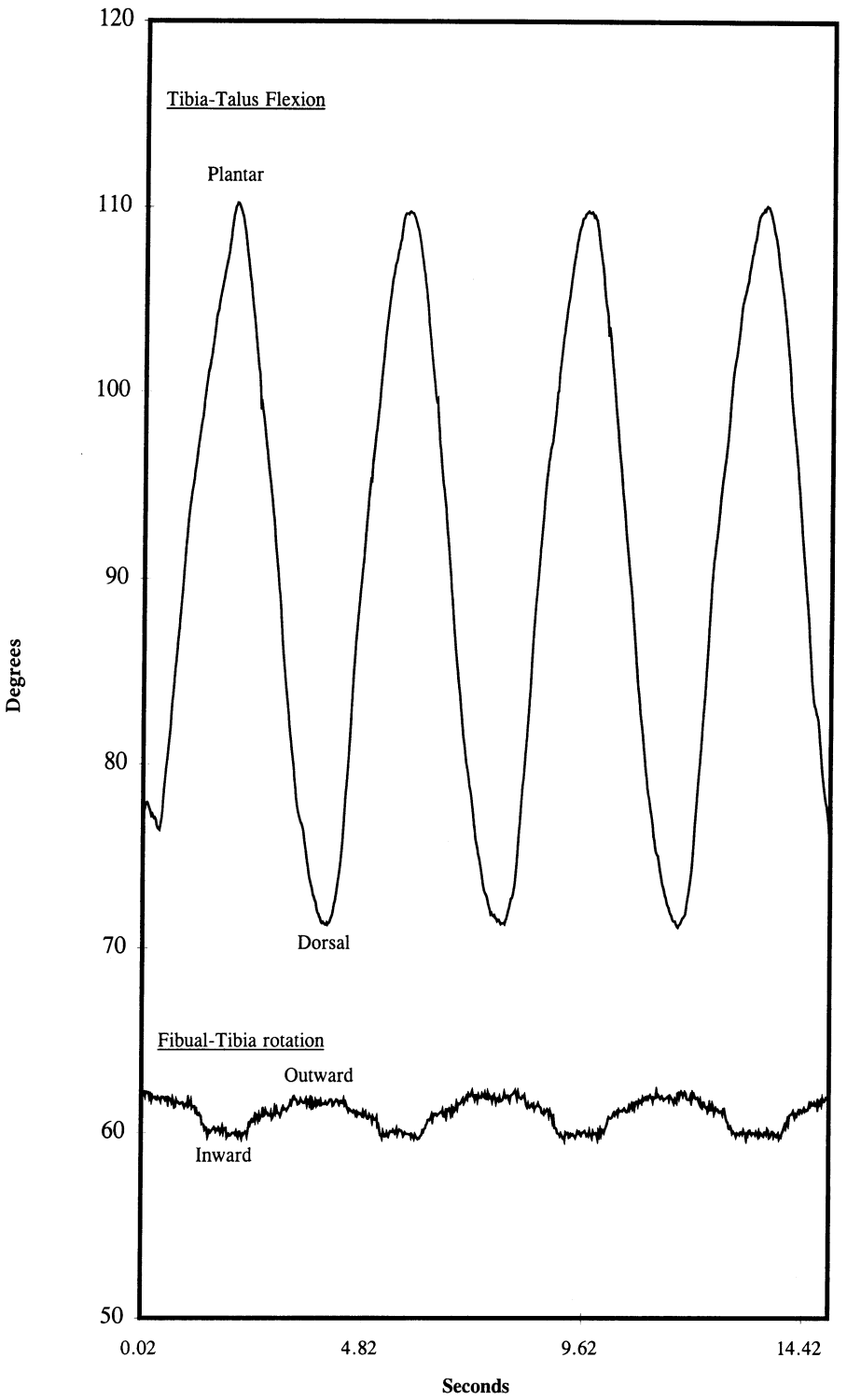


Fig. 12.2. An example showing the curves of the measured angles over time (*seconds*)

Table 12.2. Age and gender distribution. The degree of passive motion of the ankle and the corresponding rotation of the fibula. The median and range values

Number	Gender	Age (years)	Ankle motion (degrees)	Fibula rotation (degrees)
01	Male	86	57.0	2.1
02			57.1	2.8
03	Female	87	64.3	4.8
04	Female	63	47.9	1.8
05	Male	74	38.7	2.7
06			50.7	1.8
07	Male	54	27.4	1.4
08			25.9	2.2
09	Male	55	35.6	3.7
10			27.2	1.7
11	Female	76	19.4	2.6
12			16.7	2.5
13	Male	59	27.9	1.9
14			29.0	2.0
Median (range)		69 (54–87)	32 (16.7–64.3)	2.2 (1.4–4.8)

References

1. Inman VT (1976) The joints of the ankle. Williams and Wilkins, Baltimore
2. Ashhurst APC, Bromer RS (1922) Classifications and mechanism of fractures of the leg bones involving the ankle. Arch Surg 4:51–129
3. Rath G-B (1950) Widening of the ankle mortise. Acta Orthop Scand Suppl 263
4. Kärrholm J, Hansson LI, Selvik G (1985) Mobility of the lateral malleolus, a roentgen stereophotogrammetric analysis. Acta Orthop Scand 56:479–483
5. Ahl T, Dalén N, Lundberg A, et al. (1987) Mobility of the ankle mortise, a roentgenphotogrammetric analysis. Acta Orthop Scand 58:401–402
6. Lundberg A (1989) Kinematics of the ankle and foot. Acta Orthop Scand Suppl 233:60
7. Alldredge RH (1940) Diastasis of the distal tibiofibular joint and associated lesions. JAMA 115:2136–2140
8. Close JR (1956) Some applications of the functional anatomy of the ankle joint. J Bone Joint Surg 38A:761–781
9. Ledermann M, Cordey J (1979) Messung der fibularen Mitbewegung gegenüber der Tibia auf Höhe des oberen Sprunggelenkes in vivo. Helv Chir Acta 46:7–11
10. Weinert CR, McMaster JH, Ferguson RJ (1973) Dynamic function of the human fibula. Am J Anat 138:145–150
11. Cedell C-A (1975) Ankle lesions. Acta Orthop Scand 46:425–445
12. Scranton PE, McMaster JH, Kelly E (1976) Dynamic fibular function, a new concept. Clin Orthop 118:76–81
13. Reimann R, Anderhuber F, Gerold J (1986) Über die Geometrie der menschlichen Sprungbeinrolle. Acta Anat 127:271–278
14. Rasmussen O (1985) Stability of the ankle joint (thesis). Acta Orthop Scand Suppl 211:56

CHAPTER 13

Kinematic Changes of the Ankle-Joint Complex Caused by Selective Arthrodesis

B. HINTERMANN · M.D. BENNO · M. NIGG

13.1 Introduction

The main function of the ankle-joint complex is the transfer of movement between leg and foot. Many have investigated clinical results after tarsal arthrodesis, concentrating on subjective complaints and functional abilities [1, 12], or attempted to measure the residual motion left in the foot [8, 10]. Arthrodeses in the foot and ankle-joint complex were also shown to have influenced the gait substantially [2, 10]. This was explained by the created lever arms and the overall compensatory motion in the neighboring joints, rather than by changes in the mechanical coupling of foot and tibia. Although often practiced, it is still not known if and how selective tarsal arthrodesis may interfere with this coupling mechanism.

The purpose of this study was to quantify the effect of selective arthrodesis (ankle, sub-talar, and talonavicular joints) on the rotational movement of the tibia and the calcaneus, which occurs with dorsiflexion/plantar flexion. The words foot "eversion" and "inversion" refer to rotation of the calcaneus about an anteroposterior axis.

13.2 Methods

Six fresh, frozen foot-leg specimens from six different cadavers (mean age 65 years, range 48–76 years) were used for the investigation, using a 6°-of-freedom device [3–6]. After testing of the normal foot, arthrodeses of the ankle, sub-talar, sub-talar and talonavicular, and talonavicular, joints were performed using a mini-external fixator and screws.

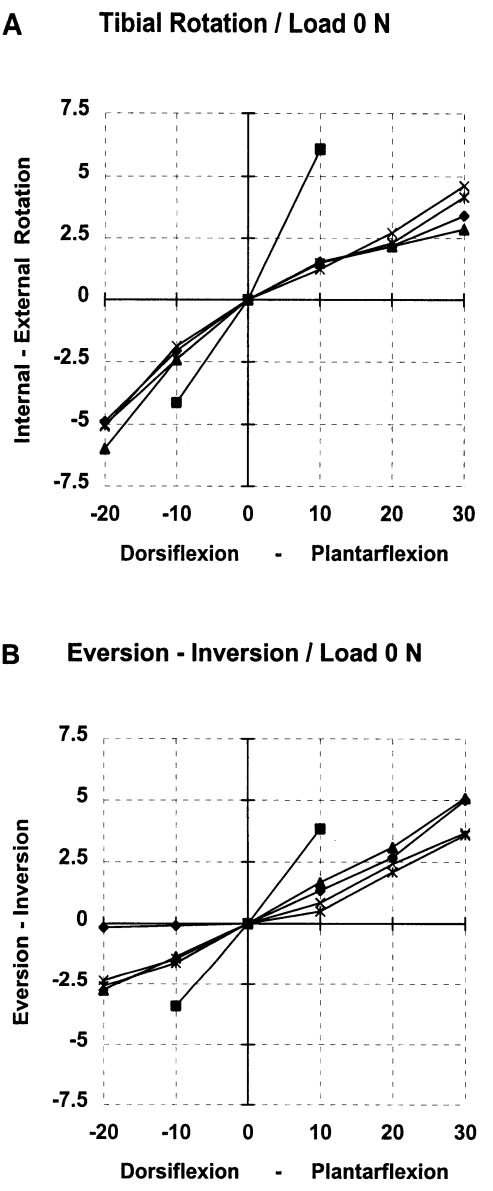


Fig. 13.1 A, B. Mean values of the resulting tibial rotation (**A**) and calcaneal eversion/inversion (**B**) during dorsiflexion/plantar flexion of the foot with and without joint fusion (adapted from [4])

13.3 Results

13.3.1 Tibial Rotation

Both foot movements, dorsiflexion and plantar flexion, resulted in a significant increase of tibial rotation when the ankle joint was fused (Fig. 13.1 A).

With respect to the physiological situation, the resulting tibial rotation in ankle-joint fusion was twice as high during dorsiflexion and even four times higher during plantar flexion. This increase was noted throughout all loading conditions. The tibial rotation for a given dorsiflexion/plantar flexion did not change in the case of the other arthrodesis conditions.

13.3.2 Calcaneal Eversion/Inversion

Contrary to the normal foot, dorsiflexion of the foot induced significant calcaneal eversion in the case of all arthrodesis conditions (Fig. 13.1 B). This change was twice as high during ankle-joint fusion. No changes were seen in calcaneal inversion for a given plantar flexion, with the exception of ankle-joint fusion. In this case, the resulting calcaneal inversion was, independently of the load, increased about three times with respect to the normal foot.

13.4 Discussion

Ankle arthrodesis still allows for about 10° for dorsal and plantar flexion of each foot [2, 5, 8, 10], and that motion is almost sufficient for the required foot flexion during normal gait [11]. As shown in the present study, the mechanical coupling between foot and tibia was highly changed after ankle arthrodesis. Ankle-joint fusion tremendously increased the tibial rotation and calcaneal eversion/inversion during dorsiflexion/plantar flexion of the foot. For the range of 10° dorsiflexion to 10° plantar flexion, the mean tibial rotation was increased from 4.1° to 10.2° (factor 2.5), and the mean calcaneal eversion/inversion from 2.2° to 7.3° (factor 3.3). The increased rotational movements of the tibia may cause higher rotational forces in the knee joint and, thus, lead to overuse injuries at the level of the knee joint. Similarly, increased rotational movements of the calcaneus may cause overuse injuries to the distal Achilles tendon [6]. Therefore, from a mechanical point of view, a prosthetic replacement of the ankle joint that allows for rotational movement about the vertical axis may cause fewer rotational forces about the knee joint and less mechanical friction of the distal Achilles tendon compared with an ankle-joint fusion.

Transformation of leg rotation into calcaneal eversion/inversion, and vice versa, has been suggested to occur mainly at the sub-talar joint [3, 7, 9]. If this is true, sub-talar joint fusion must result in a significant loss of movement transferred between calcaneus eversion/inversion and tibial rotation. However, as previously shown [5], this was not true for a given flexion position; the movement transfer between the calcaneus and tibia was not substantially reduced after sub-talar joint fusion when calcaneus eversion/inversion or tibial rotation was applied. The authors concluded that the ankle joint must provide for a significant part of this movement transfer between calcaneus and tibia, which cannot be explained, assuming the ankle joint is an ideal hinge.

In the present study, the axially loaded ankle-joint complex was taken through a range of dorsiflexion-plantar-flexion motions without external constraints. Resulting tibial rotation or calcaneal eversion/inversion from dorsiflexion/plantar flexion of the foot did not change significantly after sub-talar joint fusion when foot movement was limited strictly to rotation about the ankle-joint axis. The induced calcaneal eversion/inversion was linear throughout the range from 20° dorsiflexion to 30° plantar flexion, indicating an almost constant "axis" of the ankle joint, with respect to foot rotation. In contrast, the tibia rotated substantially more during plantar flexion than during dorsiflexion. Thus, the "axis" of the ankle with respect to the tibia must have changed during dorsiflexion/plantar flexion of the foot.

13.5 Conclusion

Ankle-joint fusion did affect the resulting tibial rotation and calcaneal eversion/inversion significantly more than all other arthrodesis conditions. This emphasizes the predominant role of the ankle joint in transferring movement within the foot-ankle complex. Consequently, ankle arthrodesis should be, if possible, avoided. An alternative would be a prosthetic replacement of the ankle joint that allows for rotational movement about the horizontal as well as the vertical axis.

References

1. Barr JS, Record EE (1953) Arthrodesis of the ankle joint: indications, operative technic and clinical experience. N Engl J Med 258:53–60
2. Hefti F (1981) Die Stellung des Fusses bei Arthrodesen des oberen Sprunggelenkes. In: Otto P (ed) Bücherei des Orthopäden. Enke Verlag, Stuttgart, pp 17–67
3. Hintermann B, Nigg BM (1995) In vitro kinematics of the axially loaded ankle complex in response to dorsiflexion and plantarflexion. Foot-Ankle 16:514–518
4. Hintermann B, Nigg BM (1995) Influence of arthrodeses on kinematics of the axially loaded ankle complex during dorsiflexion/plantarflexion. Foot-Ankle 16:633–636
5. Hintermann B, Nigg BM, Cole GK (1994) The influence of selective arthrodesis on movement transfer between calcaneus and tibia in vitro. Clin Biomech 9:356–361
6. Hintermann B, Nigg BM, Cole GK, Sommer C (1994) The transfer of movement between tibia and calcaneus. Clin Biomech 9:349–355
7. Inman VT (1976) The joints of the ankle. Williams and ialkins, Baltimore
8. Jackson A, Glasgow M (1979) Tarsal hypermobility after ankle fusion – fact or fiction? J Bone Joint Surg Br 61:470–473
9. Lundberg A (1989) Kinematics of the ankle and foot. In vivo roentgen stereophotogrammetry. Acta Orthop Scand Suppl 233:1–24
10. Mazur J, Schwartz E, Simon S (1979) Ankle arthrodesis. Long-term follow-up with gait analysis. J Bone Joint Surg Am 61:964–975
11. Stauffer RN, Chao EY, Brewster RC (1977) Force and motion analysis of the normal, diseased, and prosthetic ankle joint. Clin Orthop 127:189–196
12. Thomas FB (1967) Arthrodesis of the subtalar joint. J Bone Joint Surg Br 49:93–98

CHAPTER 14

Clinical Study of Total Ankle Arthroplasty Using Gait Analysis (5-Year Follow-Up)

S. Giannini · F. Catani · M.G. Benedetti · A. Leardini

14.1 Introduction

The implantation of ankle prostheses has been in use for about 30 years. Despite this, they are not as common as hip or knee prostheses for two basic reasons:

1. The frequency of degenerated ankle joints is far less than that of hips and knees.
2. Ankle prostheses have shown a deterioration of the initial good results within the first 5 years in 40% of the cases [1–3]. Alternative procedures, such as arthrodesis, if performed in a good position [4, 5] and with a good surgical technique [6], have produced good results after 20 years, in more than 80% of cases.

A great deal of ankle-prosthesis failure is brought about by both the stress exerted on this small joint, which has to endure shear and compression forces during its characteristic complex tri-plane movement, and the inability of these types of prostheses to absorb this stress. Analyzing the literature [1–4, 12–16, 19–21], in particular the implant-failure factors, ankle prosthesis was found to be a more precise and more limited indication for use according to age, work activity, etiology, deformity and/or sub-segmental rigidity. At the same time, new models of prosthesis – the three component prostheses [low contact stress (LCS), Scandinavian total ankle replacement (STAR)] that have, as a particular feature, a free-gliding core – are being made with the aim of reducing the two main causes of failure: the loosening and the impingement syndrome [7, 8, 18–21]. Now the clinical need is to verify the joint function utilizing this three-component prostheses to understand the effectiveness of the implant design and surgical technique.

Most of the time it is very difficult to assess the lower-limb function, particularly the ankle-foot biomechanics, due to the multi-joint involvement of the disease and the degenerative changes of all the articular or periarticular tissues. The fundamental cause in the failure of the ankle prostheses is the lack of knowledge of the axial and rotational loads that are transferred to the ankle by the lower limb and the impaired soft tissue,

which are inefficient to lead or to constrain the joint kinematics. In fact, as in all the prosthetic implants, the clinical and biomechanical success is strictly related to the balance between prostheses design and soft-tissue tensioning. These factors were considered in the design of the so-called three-component replacement, where the main factor is a free-gliding core. For this reason, we assessed LCS-prostheses patients using the gait-analysis technique.

14.2 Materials and Methods

Between May 1990 and November 1992, 11 total ankle replacements were performed on ten patients. One patient underwent bilateral implantation. The mean age was 65 years (range 59–76 years). Eight were female and two were male. The average follow-up was 5 years (range 4.5–7 years). Clinical (Mazur [17] modified score) and radiographical (Unger [9] and Wesely [10]) assessments were made on all patients; gait analysis [3-D stereophotogrammetry system – elite, two forceplates and eight-channel electromyogram (EMG)] was carried out on six patients. Five patients were suffering from unilateral rheumatoid arthritis (RA), one from bilateral RA. Four were suffering from arthritis, three of which occurred secondary to injury (one patient had undergone hip arthrodesis following acetabular fracture), and one patient was suffering from arthritis secondary to an unknown juvenile infective disease.

14.3 Results

The clinical assessment showed that patients with ankle prostheses did not feel pain when walking. This symptom appeared slightly when walking long distances and going down stairs. Patients were able to raise themselves up onto tip toes five or ten times, showing fairly good plantar-flexor function. However, a difference was found between this ability and hypotrophy of the operated limb. The patient with hip arthrodesis experienced a failure of the implant, with the erosion of the polyethylene in the lateral component due to rotation overstress for the altered lower-limb biomechanics. Two polyethylene revisions were necessary; the first time, a calcaneus osteotomy was also performed. Hind-foot realignment was not enough to compensate the abnormal rotational stress of the lower limb. In subsequent (post-operative) X-ray assessments of all patients, correct alignment of the talar and tibial components was maintained in the center of rotation, and there was no significant change in alignment of the anatomical axis. Assessment of the X-Ray shows a range of motion with greater reduction in plantar flexion. Areas of radiolucency were found in eight patients, even in the first radiological assessment; in the second assessment, the site and grade were the same.

Gait analysis showed: (1) walking velocity is reduced with the decrease in cadence and stride length – gait is symmetric and rhythmic; (2) the vertical and the antero-posterior components of the ground-reaction force are reduced both in the loading response and the push-off phase, in part because of the decrease in walking velocity. The propulsive phase was impaired with a reduction of active plantar flexion in the terminal stance phase; (3) the kinematic alteration in the ankle was symmetrical. There was increased plantar flexion in the heel strike and decreased dorsiflexion in the mid-stance, terminal stance and pre-swing phases; and (4) in the external joint movement, the ankle showed a marked reduction of dorsiflexion movement on terminal stance and pre-swing phase with a deficit in the push off.

The electromyography showed: (1) that the rectus femoris and the biceps femoris have prolonged activity up to mid-stance phase, which is considered a protective action to stabilize the weight-bearing limb; (2) the particular premature activation of the peroneal longus in the terminal swing, which enables initial stance with the plantar flexed ankle; (3) that the tibialis anterior behaves normally; and (4) that the gastrocnemius had a wide range of activation, though near to normal. Finally, it was interesting to notice how the non-operated side tended to mimic the pattern of movement of the operated side to maintain a certain symmetry while walking.

14.4 Conclusions

This study confirms that the indications for the treatment are limited to post-traumatic arthritis in patients over 65 years of age or RA without marked osteoporosis, especially when the compensatory mechanism is reduced because of involvement of other foot joints and sovra-segmentary joints. These two main indications show that to have a successful ankle prosthesis, the level of activity needs to be reduced and, therefore, so does the level of mechanical demand on the prosthesis. This is why it is necessary to look for hip-, knee- or foot-joint deformities causing overstressing.

The advantage of a mobile-bearing prostheses was shown in the gait study that quantified symmetric kinematics, overall good kinematics and kinetics, and compensated muscle-activity changes.

In conclusion, using the implant only for those cases listed above, with a three-component prosthesis implanted with good surgical technique, there can be an improvement in the number of good results. Our results after 5 years average follow-up do not allow us to draw definite conclusions, but they give us hope of further improvement of fixation systems and prosthetic design.

References

1. Lachiewicz PF, Inglis AE, Ranawat CS (1984) Total ankle replacement in the rheumatoid arthritis. J Bone Joint Surg Am 66:340
2. Bolton-Maggs BG, Sudlow RA, Freeman MAR (1985) Total ankle arthroplasty: a long-term review of the London Hospital experience. J Bone Joint Surg Br 67:785
3. Johnson KA (1991) Ankle replacement arthroplasty. In: Joint replacement arthroplasty. Churchill Livingstone, New York, pp 1173–1182
4. Demottaz JD, Mazur JM, Thomas WH, Sledge CB, Simon SR (1979) Clinical study of total ankle replacement with gait analysis: a preliminary report. J Bone Joint Surg Am 61:976
5. Giannini SE (1992) Coll. Le protesi del piede Giot. Supplemento Congresso SIOT
6. Calandruccio R (1985) Triangular compression Dence. Richards Medical Company, Indiana
7. Buechel FF, Pappas MJ, Iorio LI (1988) New Jersey low contact stress total ankle replacement: biomechanical rationale and review of 23 cementless cases. Foot Ankle 8:6
8. Keblish PA (1990) Porocoat New Jersey Ankle. Annual Report
9. Unger AS, Inglis AE, Mow CS, Figgie H (1988) Total ankle arthroplasty in rheumatoid arthritis: a long-term follow-up study. Foot Ankle 8 (4):173–179
10. Weseley MS, Koval R, Kleiger B (1969) Roentgen measurement of ankle flexion-extension motion. Clin Orthop 65:167
12. Mcguire MR, Kyle RF, Gustilo RB, Premer RF (1988) Comparative analysis of ankle arthroplasty versus ankle arthrodesis. Clin Orthop 226:174–181
13. Newton E (1982) Total Ankle Arthroplasty. J Bone Joint Surg 64-A:104–111
14. Vittore D, Mori F, Gioia G (1992) Le protesi di caviglia. In: Gaggi Aulo (ed) Progressi Medicina e Chirurgia del Piede
15. Pipino F, Calderale PM (1985) Protesi di caviglia. Chirurgia del Piede 9:331–336
16. Takakura Y, Tanaka Y, Sugimoto K, Tamai S (1990) Ankle arthroplasty. A comparative study of cemented metal and uncemented ceramic prostheses. Clin Orthop 252:209
17. Mazur JM, Schwartz E, Simon SR (1979) Ankle arthrodesis. Long-term follow up with gait analysis. J Bone Joint Surg Am 61:964
18. Buechel FF (1983) The New Jersey total ankle with porocoat: surgical procedure. DePuy (Division of Boehringer Mannheim), Warsaw
19. Bauer G, Eberhardt O, Rosenbaum D, Claes L (1996) Total ankle replacement. Review and critical analysis of the current status. Foot Ankle Surg 2:119–126
20. Garde L, Kofoed H (1996) Meniscal-bearing ankle arthroplasty is stable. In vivo analysis using stabilometry. Foot Ankle Surg 2:137–143
21. Kofoed H (1995) Cylindrical cemented ankle arthroplasty: prospective series with long-term follow-up. Foot Ankle Int 16:474–479

CHAPTER 15

The Value of Ankle Prostheses – A Gait Analysis Approach

R. G. H. H. Nelissen · H. C. Doets · C. Meskers

15.1 Introduction

The major causes of ankle arthrosis are ankle fractures and rheumatoid arthritis. The incidence of post-traumatic arthrosis within 18 months after an ankle fracture ranges from 10% to 85%, depending on the amount of post-treatment fracture reduction (Geissler 1996). More than 90% of all rheumatoid arthritis patients between 40 years and 60 years of age have foot and ankle manifestations (Scardina 1997).

Fusion of the ankle still remains the most practised treatment for primary and secondary, i.e. rheumatoid arthritic, arthrosis of the ankle. Fusion of the ankle produces painlessness, but also, due to its nature, more strain on the kinetic chain of the other lower extremity joints, i.e. knee joint and fore foot. The unpopularity of ankle prostheses is mainly based on literature reports of studies in which a constrained type of prosthesis was used (Bolton 1985; Kitaoka 1994, 1996).

The purpose of ankle arthroplasty is to decrease pain and improve function of the lower limb. Pain is usually the major disabling factor and, although pain cannot be measured directly, it can be assessed indirectly by measurements that are sensitive to even slight changes in functional performance (Berman et al. 1987; Murray et al. 1995). Gait analysis, by a variety of methods, has been found to be more sensitive than clinical evaluation in detecting and quantifying the results of total joint replacement (Berman et al. 1987). Repeatability of gait variables is an important consideration in the clinical use of results of quantitative gait analysis (Kadaba et al. 1989).

Advantages of a "mobile" ankle are obvious; more functionality and less strain on the other lower-extremity joints. To investigate this, a gait-analysis study was performed in patients with a non-constrained ankle prostheses [low contact stress (LCS), DePuy].

15.2 Materials and Methods

15.2.1 Subjects

Five patients with an ankle prosthesis (LCS, DePuy) (four females and one male) and two patients (both male) with an ankle arthrodesis were included in the study. The contralateral leg was considered the reference leg. Patients were 64 years old (SD 2.0). Clinical performance of the ankle was determined by measuring an ankle score (Buechel 1992).

15.2.2 Kinematic Analysis

Subjects walked on a motor-driven treadmill at a free-walking pace (Kadaba et al. 1989) for 15 min to get acquainted to the apparatus and to determine the most comfortable walking speed for testing. Walking speed ranged from 1.6 to 3.75 km/h (mean 2.5 km/h, SD 0.82) among subjects.

To record the time factors during a walking cycle, foot switches were attached to two points of the shoe sole. These switches were able to make contact with the surface of the treadmill. The shoe soles were made of conducting rubber. Thus, calculation of stride-time parameters and synchronization of electromyographic and goniometric data could be performed. The stance, swing and step duration were calculated for the operated and the control leg, as well as symmetry ratio, double-support time, cycle duration and step length. The knee and ankle flexion of both legs was recorded by electrogoniometers.

15.3 Results

All patients had an excellent result, as determined clinically and radiographically. The mean ankle score for the ankle prostheses was 89 points (SD 7.9). No patient experienced pain at follow-up. Mean dorsiflexion was 8° (SD 3.6) and plantar flexion was 29° (SD 8.5), as measured prior to gait analysis.

During gait, the mean ankle flexion in ankle prostheses at heel strike was 8° plantar flexion, which changed to 9° at the loading response (Perry 1992) at the initial-stance phase. At the initial-swing phase of the knee (60% of gait cycle), 12° plantar flexion occurred. The maximum plantar flexion in the prosthesis ankle was slightly less compared with the normal ankle (Fig. 15.1).

At the initial-stance phase, plantar flexion ranged from 1° to 10° and at the initial-swing phase, the plantar flexion ranged from 8° to 16°. In the arthrodesed ankle joints, 7° range of motion occurred in the mid- and fore foot (Fig. 15.2).

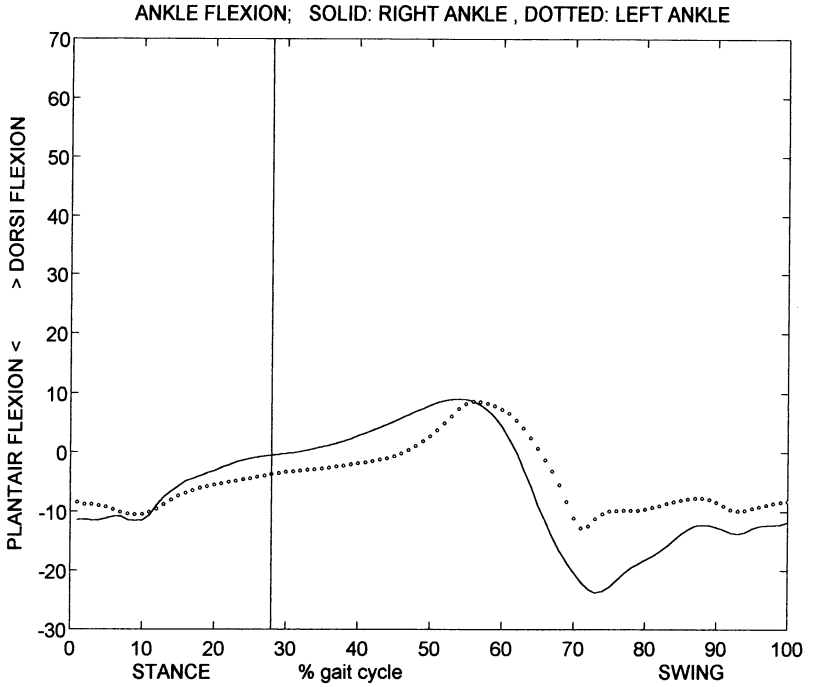


Fig. 15.1. Gait cycle and ankle motion. Left ankle has ankle prosthesis

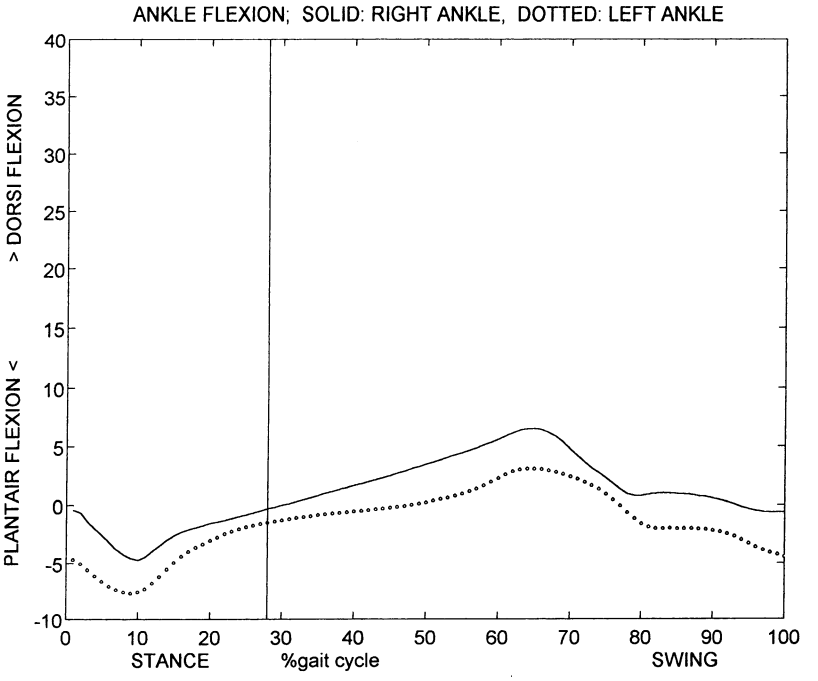


Fig. 15.2. Gait cycle and ankle motion. Left ankle is arthrodesed

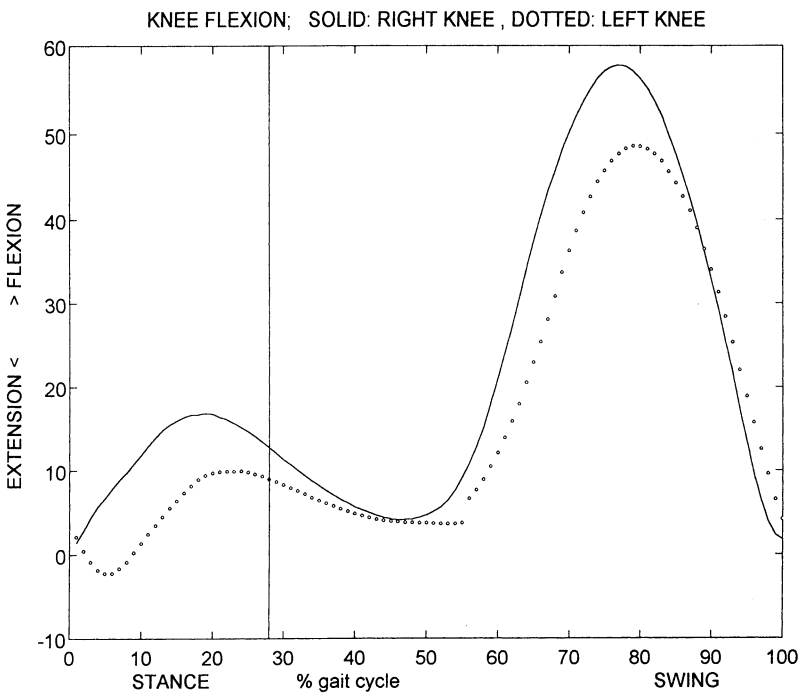


Fig. 15.3. Gait cycle and knee motion. Left leg has an ankle prosthesis

During gait, the knee-flexion curve in the ankle-prosthesis leg was similar to normal patterns from the literature (Perry 1992). The knee flexion in the ankle-prosthesis leg showed only a slight hyperextension at heel strike, followed by normal flexion at loading response during the initial stance and a normal curve pattern during swing phase (Fig. 15.3). However, maximum flexion at the swing phase was less (48°) than in the reference leg (56°). However, the knee-flexion pattern in the ankle-arthrodesis leg was different from normal curve patterns (Fig. 15.4). This curve pattern showed constant knee flexion throughout the gait cycle, with little increase of knee flexion at the initial stance, i.e. loading response was little in the arthrodesed leg.

15.4 Discussion

In this study, the ankle-prosthesis legs demonstrated knee- and ankle-flexion-curve patterns during gait that were similar to normal values from the literature (Perry 1992). However, slightly lower absolute values were present. The normal functional range of the ankle joint is from 10° dorsiflexion to 30° plantar flexion (Perry 1992), which was similar with static measurements from this study population. Thus, lower absolute ankle-flexion values may be due to adaptation of proprioceptors to pre-operative joint destruction, or to higher friction coefficients within an artificial joint than a normal joint.

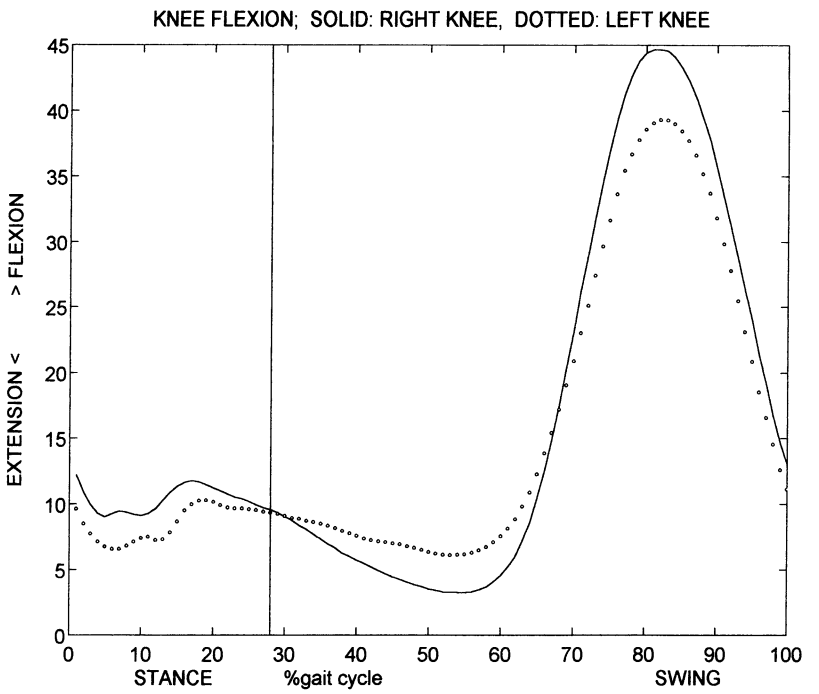


Fig. 15.4. Gait cycle and knee motion. Left leg has an ankle arthrodesis

The range of motion of normal ankle movement and the function of this joint to transmit vertical weight-bearing forces to a horizontal support system makes it obvious that arthrodesis of this joint creates more strain on adjacent joints, i.e. knee, sub-talar, foot. In this study, this was shown by the abnormal knee-flexion pattern at the stance phase in the ankle-arthrodesis leg and the slight flexion in mid- and fore foot. Kofoed and Stürup (1994) noted more arthrosis in sub-talar joints after ankle arthrodesis.

Some authors (Demottaz et al. 1979) reported abnormal gait patterns after ankle replacement, which were explained by weakness of calf and peroneal muscles. However, in that study, only 40% of all studied subjects experienced no pain in the prosthetic joint. As has been discussed by others (Murray et al. 1995), even slight pain in a lower extremity joint will have a significant effect on gait-analysis data.

The option of an ankle prosthesis not only creates better kinesiological patterns for the lower extremity, which can be valuable especially in the multiple-joint involvement rheumatoid arthritis patient, but also makes a salvage procedure possible with good clinical results in case of a failure (Groth and Fitch 1987). Furthermore, outcome results may be improved by the new-generation meniscal-bearing total ankle replacements (Buechel 1992; Kofoed 1995) and surgical expertise on the procedure and indication.

References

Berman AT, Zarro VJ, Bosacco SJ, Israelite C (1987) Quantitative gait analysis after unilateral or bilateral total knee replacement. J Bone Joint Surg Am 69:1340–1345

Buechel FF, Pappas MJ, Lorio LJ (1988) New Jersey contact stress total ankle replacement: biomechanical rationale and review of 23 cementless cases. Foot Ankle 8:279–290

Demottaz JD, Mazur JN, Thomas WH, Sledge CB, Simon SR (1979) Clinical study of total ankle replacement with gait analysis: preliminary report. J Bone Joint Surg Am 61:976

Geissler WB (1996) Fractures and injuries of the ankle. In: Rockwood, Green (eds) Fractures in adults (4th edn). Lippincott, Philadelphia

Groth HE, Fitch HF (1987) Salvage procedures for complications of total ankle arthroplasty. Clin Orthop 224:245–249

Kadaba MP, Ramakrishnan HK, Wootten ME, Gainley J, Gorton G, Cochran GVB (1989) Repeatability of kinematic, kinetic, and electromyographic data. J Orthop Res, pp 849–860

Kofoed H (1995) Cylindrical cemented ankle arthroplasty: a prospective series with long-term follow-up. Foot Ankle 16:474–478

Kofoed H, Stürup J (1994) Comparison of ankle arthroplasty and arthrodesis. A prospective series with long-term follow-up. The Foot 4:6–9

Mazur JN, Schwartz E, Simon SR (1979) Ankle arthrodesis: long-term follow-up with gait analysis. J Bone Joint Surg Am 61:964

Murray MP, Gore DR, Sepic SB, Mollinger LA (1995) Antalgic maneuvers during walking in men with unilateral knee disability. Clin Orthop 199:192–200

Perry J (1992) In: Perry J (ed) Gait analysis, normal and pathological functions. Slack Incorporated, Thorofare

CHAPTER 16

In Vivo Stabilometry of Meniscal-Bearing Ankle Prosthesis*

E. Magnussen · L. Garde · H. Kofoed

16.1 Introduction

Ankle arthroplasty has previously had a dubious reputation based on the experience with the first-generation two-piece designs. This has given the impression that ankle arthrodesis is the preferable choice in painful and degenerate ankles when conservative treatment has failed. Introducing a sliding meniscus in a prosthetic ankle joint resulted in a better performance, especially by imitating the normal torque and, thereby, decreasing stress at the bone-prosthesis interface.

Cadaver study has shown that a meniscal-bearing ankle arthroplasty gives normal ankle mobility and rotator stability, but could lead to increased antero-posterior laxity. This was thought to result in ligament stress and subsequently failure of the prosthesis [1].

Only a few studies tried to analyse the kinematics of an ankle arthroplasty in situ and these showed reduced velocity, cadence and step length. Therefore, a cylindrical, meniscal-bearing and anatomically uncemented (hydroxy-apatite-coated) ankle prosthesis [2] was analysed kinematically in vivo by stabilometry. This is a precise method for analysing minimal displacements and their speed in any direction from a zero position [3].

16.2 Materials and Methods

Eight consecutive patients were treated with a unilateral uncemented ankle arthroplasty during the period 1990–1992. They all met the following criteria:

1. Unilateral painful secondary osteoarthritis of the ankle without sub-talar joint arthritis.
2. The leg was normal in all other respects.
3. The opposite was leg normal in all respects.

There were three females and five males in the series. Their mean age was

* This paper has been published in full in [4].

56 years (42–79 years). The diagnoses leading to secondary osteoarthritis in the ankle were: conservatively treated malleolar fracture [4], malleolar fracture treated with open reduction internal fixation (ORIF) [3] and old lateral ligament rupture [1].

The Scandinavian total ankle replacement (STAR) ankle prosthesis (Waldemar Link Co., Germany) was used. It consists of three parts: a talar component, a tibial glide plate and a polyethylene meniscus that is congruent with the other two components. The talar component is nearly anatomically shaped, with medial and lateral flanges to cover the talar facets. A ridge on the dome corresponds to a groove in the polyethylene meniscus. This only allows extension flexion between talus and meniscus, whereas torque and a slight anterior-posterior gliding are possible between the meniscus and the tibial glide plate.

A stabilograph (CS-Medico, Denmark) was used in the study. It is based on a static force plate, which – through a computer – records the square area used to keep the unsupported balance on one leg. It also records the direction and length of all corrective movements as well as their velocity.

The balance test was performed twice for each leg, with and without shoes and with open and closed eyes. The best of two tests for each side and for each set-up was taken as the normal performance. Each balance test lasted 21 s. None of the patients was able to perform a one-legged stand on the arthritic ankle before the operation. Follow-up at the time of the balance tests was at mean 2.5 years (1.5–3.5).

16.3 Results

The preoperative mean score was 29 (12–46). At the follow-up, the mean score was 91 (84–99). A comparison between preoperative scores and scores at follow-up showed a significant decrease in pain and, likewise, a significant increase in function and mobility ($p<0.001$). Furthermore, it showed a significant negative correlation between the preoperative total score and the final score.

The stabilometric analysis showed no difference between normal and artificial joints. Area and velocity, used to keep the unsupported balances, were the same, as were the length and direction of the corrective movements. In the artificial joint, however, the velocities of the corrective movements were faster in the antero-posterior direction ($p<0.05$). This is most probably explained by the construction of the prosthesis.

16.4 Discussion

The study showed normal performance of the artificial ankle in the standing phase, with stability the same as that of the normal joint. There was no clini-

cal or stabilometric evidence for overloading of the ankle ligaments. It should, however, be mentioned that the cadaver model used by Burge and Evans [1] was a spheroid design. In such designs, it may be likely that the ligaments' apparatus will have to take the loading to stabilise the artificial joint.

References

1. Burge P, Evans M (1986) Effect of surface replacement ankle arthroplasty. Foot Ankle 7:10–17
2. Kofoed H, Danborg L (1995) Biological fixation of ankle arthroplasty. Foot 5:27–31
3. Tropp H, Ekstrand J, Gillquist J (1984) Stabilometry in functional instability of the ankle and its value in predicting injury. Med Sci Sports Exerc 16:64–66
4. Garde L, Kofoed H (1996) Meniscal bearing ankle arthroplasty is stable. In vivo analysis using stabilometry. Foot Ankle Surg 2:137–143

Ankle Arthroplasty and Rheumatoid Arthritis

CHAPTER 17

First Experience and Early Results with an Uncemented Total Ankle Arthroplasty

E. Funke · P. Rippstein · U. Munzinger

17.1 Introduction

Ankle arthroplasty is still a controversial procedure. In a long-term follow-up, Kofoed [1] demonstrated very good results and stated that it may be the treatment of choice for painful degenerated ankle joints. On the other hand, there is increasing concern about the long-term results of ankle arthrodesis [2, 3], regarding gait pattern, deterioration at a variable rate in the sub-talar and mid-tarsal joints and possibly even in the knee joint. Being aware of the limitations of ankle arthrodesis, we started in 1996 with the Scandinavian total ankle replacement (STAR) ankle prosthesis.

17.2 Materials and Methods

Seven consecutive patients were treated with eight uncemented congruent and cylindrical total ankle arthroplasties during 1996 at the Schulthess Hospital, Zürich. The patients were informed about ankle arthrodesis and uncemented ankle arthroplasty and made their own choices. They all opted for ankle arthroplasty.

This prospective study consists of two females and three males (one bilateral) with a minimum 6-month follow-up. The diagnoses were post-traumatic and rheumatoid arthritis in two patients each and haemochromatosis in one (bilateral case). The average age was 53 years (38–62 years). The patients were evaluated prospectively by two ankle scoring systems; one described by Kofoed (KOF) and the other by the American Foot and Ankle Society (AFAS). Radiographs were taken after surgery and at follow-up visits. Image intensification was used to obtain straight antero-posterior (AP) and lateral views.

17.3 Results

Figure 17.1 shows the pre-operative and post-operative score of each patient. Pre-operatively, they scored a mean of 26 points with KOF and 28 points with AFAS. At the latest follow-up, they recorded 75 points. (AFAS 71 points). Table 17.1 demonstrates the improvement in scoring points. The most improvement was due to pain relief (33 points), followed by better function (11 points) and more mobility (3 points). Patients with rheumatoid arthritis or haemochromatosis showed the best improvement (60 points) and are very satisfied with their ankle prosthesis. One patient with post-traumatic osteoarthritis had an acceptable result (70 points), whereas the other was dissatisfied (34 points). On the short-term follow-up, there was no radiographic loosening or migration. There was no infection, no wound-healing problems and no nerve damage.

17.4 Discussion

There is still an ongoing discussion whether ankle arthroplasty makes sense. The results of the first-generation prosthesis led to the abandonment of ankle replacement for most orthopaedic surgeons. The good long-term results of the STAR ankle prosthesis are promising and enable the surgeon to offer the patient an alternative to ankle arthrodesis. In our short-term study, patients

Table 17.1. Improvement following ankle arthroplasty

	praeOP	postOP	
Pain 50	5	38	33
Function 30	11	22	11
Mobility 20	11	14	3

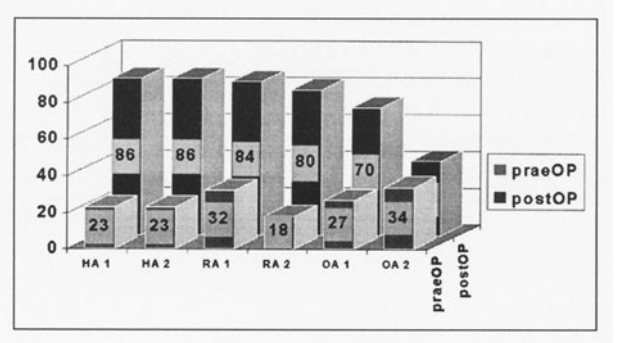


Fig. 17.1. PreOP and postOP ankle scores (KOF)
HA = haemochromatosis, *RA* = rheumatoid arthritis, *OA* = posttraumatic osteoarthritis

with rheumatoid arthritis or haemochromatosis got a better result with ankle arthroplasty, whereas post-traumatic cases seem to have more problems. On the other hand, Kofoed [4], in a long-term study, couldn't find a significant difference between the results of rheumatoid arthritis and osteoarthritis patients. We think that further prospective studies are needed to draw conclusions.

References

1. Kofoed H, Stürup J (1994) Comparison of ankle arthroplasty and arthrodesis. A prospective series with long-term follow-up. Foot 4:6–9
2. Broquin J, Emani A, Maurer P, Tomeno B (1979) Arthrodesis of the ankle. A study of the complications and long-term results. Rev Chir Orthop Reparatrice Appar Mot 65:393–401
3. Leicht P, Kofoed H (1992) Subtalar arthrosis following ankle arthrodesis. The Foot 2:89–92
4. Kofoed H (1995) Cylindrical cemented ankle arthroplasty: a prospective series with long-term follow-up. Foot Ankle 16:474–479

CHAPTER 18

Medium-Term Results in Rheumatoid Arthritis with the Bath and Wessex Ankle Prosthesis*

Å. S. Carlsson · A. Henricson · L. Linder · J.-Å. Nilsson · I. Redlund-Johnell

18.1 Introduction

Since the first implantation of a "true" ankle prosthesis at the Endoklinik in Hamburg in 1972 (Buchholz et al. 1973), at least 20 different designs have been described. Beginning in the mid 1980s, prostheses intended for use without bone cement and with or without meniscus function have appeared (Scholz 1987; Buechel et al. 1988; Takakura et al. 1990; Kofoed and Stürup 1994).

The Bath and Wessex total ankle prosthesis is a cemented non-constrained design introduced in 1980 by John Kirkup (1990) (Fig. 18.1). Here we review the clinical and radiographic results, including analyses of survival, in a consecutive series of Bath and Wessex ankles, implanted in patients with rheumatoid arthritis (RA). The material has previously been published as a full paper in *The Foot* (Carlsson et al. 1994).

18.2 Materials and Methods

Between 1984 and 1991, we implanted 55 Bath and Wessex ankle prostheses in RA patients. Excluding three ankles that became infected, 52 ankles in 47 patients remained for analysis. There were 43 females and 4 males. The age at surgery ranged from 32 years to 72 years, with the median age being 62 years. Of the 47 patients, 25 were undergoing or had previously received systemic steroid treatment. Postoperatively, a posterior plaster shell was usually applied for 10 days in order to assist wound healing – thereafter full weight bearing was permitted.

* By permission of the editor of *The Foot*.

Fig. 18.1. The Bath and Wessex total ankle. Reproduced from Kirkup (1990), with permission from the author and the British Medical Association

18.2.1 Radiographic Methods

Loosening of the tibial component was defined as a change of the angles between the base of the component and the long axes of the tibia in the anteroposterior (AP) and/or lateral views, or as a radiolucent line between the bone and cement greater than 2 mm. In the AP view, a change of the distance exceeding 2 mm between the base of the tibial component and the tip of the lateral malleolus was considered a sign of loosening.

Loosening of the talar component was most easily observed in the lateral view. It was defined as a change of the angle between a line drawn through the base of the talar component and another from the upper posterior part of the tuber of the calcaneus and the most dorsal aspect of the talonavicular joint. For loosening, we required a change of greater than 3°. The perpendicular distances from the latter line to the lower anterior and posterior borders of the talar component were also measured, and a change of more than 2 mm was regarded as subsidence and loosening. In contrast to a reference line through the plantar aspect of the calcaneus, as proposed by Lachiewicz et al. (1984), the former line is not influenced by progressing changes in the sub-talar joints. A drawing demonstrating the above mentioned angles and reference lines can be found in the original paper (Carlsson et al. 1994).

18.3 Results

Radiographic loosening of both components was observed in 8 cases, loosening of only the talar component in 17 cases and loosening of only the tibial component in 1 case. At no time was the diagnosis based only on the presence of bone-cement lucencies. In eight cases, pain and walking difficulties recurred, leading to arthrodesis in four and exchange of one or both components in four cases.

The results of the radiographic and clinical survival analyses are presented in life-tables (Table 18.1). The radiographic survival rate at 5 years was 0.33 (95% CI 0.16–0.49) for the talar component and 0.65 (95% CI 0.45–0.85) for the tibial component. The clinical survival rate at 5 years, i.e. the probability that the prosthesis had not been revised, was 0.81 (95% CI 0.67–0.95).

Of the 27 ankles with radiographically intact talar components, 15 were completely pain free at the last follow-up and the remaining 12 had only slight pain during or after walking. Of the 25 ankles with a radiographically loose talar component, 15 were reported painless or much improved compared with their preoperative condition. The remaining ten ankles caused either moderate or severe pain and in eight of these cases another operation was performed.

Table 18.1. Estimated cumulative success rate of Bath and Wessex ankles, in which success is defined as: **a** the tibial component being radiographically intact; **b** the talar component being radiographically intact; **c** the prosthesis not being revised

	Time interval (years)	Number at start	Number failed	Number censored	Cumulative success rate at end of interval	95% confidence limits	
a	0–1	52	0	3	1.00	1.00	1.00
	2	49	0	6	1.00	1.00	1.00
	3	42	4	8	0.90	0.80	0.99
	4	31	2	12	0.83	0.70	0.95
	5	17	3	5	0.65	0.45	0.85
	6	9	0	4	0.65	0.45	0.85
	7	5	0	4	0.65	0.45	0.85
b	0–1	52	2	3	0.96	0.91	1.00
	2	47	5	6	0.85	0.75	0.95
	3	36	9	5	0.62	0.47	0.77
	4	22	8	4	0.37	0.21	0.53
	5	10	1	4	0.33	0.16	0.49
	6	5	0	4	0.33	0.16	0.49
c	0–1	52	0	1	1.00	1.00	1.00
	2	51	0	6	1.00	1.00	1.00
	3	45	1	6	0.98	0.93	1.00
	4	38	2	5	0.92	0.83	1.00
	5	31	3	11	0.81	0.67	0.95
	6	17	1	6	0.75	0.58	0.92
	7	10	1	5	0.66	0.45	0.86

18.4 Discussion

Although the radiographic survival of the talar component was only 33% at 5 years, 42 of all 52 ankles were reported improved at the last visit. Also, an estimated 81% of the ankles did not have to be revised after 5 years. A similar figure was reported by Kirkup (1990) – 44 of the 51 ankles (86%) studied by him, followed for an average of 4.2 years, had not been revised. A comparison with other designs is difficult because the series presented, with few exceptions, do not comprise more than 30 cases. In addition, the diagnoses are a mixture of RA and post-traumatic osteoarthritis.

In contrast to fusion, replacement using the Bath and Wessex ankle is a fairly simple procedure that requires only a short time of hospitalization, and weight bearing is allowed after only a few days – the latter being particularly important in RA. However, the Bath and Wessex total ankle, like other cemented designs, has drawbacks; notably, the difficulty to achieve long-term fixation of the talar component. The reason for this is that the talus at the implantation site has a very dense structure, even in patients with advanced osteoporosis, rendering adequate interlock between bone and cement difficult. Also, the small interface area, large loads and the narrow operative field contribute to the problems. When performing a Bath and Wessex ankle replacement, the polyethylene-tibial component is inserted first and then the load is better distributed. In addition, cementation is easier owing to a wider operative field and efficient instrumentation to hold the component and exert compression during cementation. This is reflected in the superior radiographic survival of the tibial component.

References

Buchholz HW, Engelbrecht E, Siegel A (1973) Totale Sprunggelenksendoprothese Modell „St. Georg". Der Chirurg 44:241–244

Buechel FF, Pappas MJ, Iorio LJ (1988) New Jersey low contact stress total ankle replacement: biomechanical rationale and review of 23 cementless cases. Foot Ankle 8:279–290

Carlsson ÅS, Henricson A, Linder L, Nilsson J-Å, Redlund-Johnell I (1994) A survival analysis of 52 Bath & Wessex ankle replacements. The Foot 4:34–40

Kirkup J (1990) Rheumatoid arthritis and ankle surgery. Ann Rheum Dis 49:837–844

Kofoed H, Stürup J (1994) Comparison of ankle arthroplasty and arthrodesis. A prospective series with long-term follow-up. The Foot 4:6–9

Lachiewicz PF, Inglis AE, Ranawat CS (1984) Total ankle replacement in rheumatoid arthritis. J Bone Joint Surg Am 66:340–343

Scholz KC (1987) Total ankle arthroplasty using biological fixation components compared to ankle arthrodesis. Orthopedics 10:125–131

Takakura Y, Tanaka Y, Sugimoto K et al. (1990) Ankle arthroplasty. A comparative study of cemented metal and uncemented ceramic prostheses. Clin Orthop 252:209–216

CHAPTER 19

Ankle Arthroplasty: A Clinical Follow-Up

S. Schill · H. Thabe

19.1 Introduction

The frequency of ankle joint involvement in rheumatoid arthritis (RA) varies between 15% and 50% [1, 3]. Joint destruction and functional tendon insufficiency lead to joint instability and severe hind-foot deviation with a pes plano-valgus deformity [4].

This painful destroyed ankle joint may become the most important factor in determining the mobility of a rheumatic patient. Our indication for operative treatment in the advanced SLE (systemic Lupus erythematosis) stages 4 and 5 includes either ankle arthrodesis or ankle prosthesis [2].

The disadvantages of ankle fusion, which is still dominating the surgical treatment, are long-lasting external fixation and increased mechanical stress for neighbouring joints. The risk of pseudarthrosis and loss-of-gait facilities are further negative factors.

The total ankle arthroplasty is advantageous in early remobilization and in an upkeep of gait mobility. Therefore, total ankle arthroplasty is of extreme benefit for rheumatic patients. The success of ankle arthroplasty depends on indication, implant design and surgical technique, as well as on postoperative treatment. Our indications for ankle arthroplasty are:

1. Painful ankles in RA with a minimum of preserved joint function
2. Sufficient bone stock of talus and intact ligament stability
3. Varus/valgus deviation less than 10°
4. Possibility to correct hind-foot disorders

19.2 Materials and Methods

From July 1984 to September 1996, 49 ankles in 47 patients underwent total ankle replacement. Two patients were treated bilaterally, 27 were replaced with the Thompson-Richards Prosthesis (TRP) using cement and 22 with the cementless STAR prosthesis. Three cases with STAR and four ankles treated with TRP were combined with sub-talar arthrodesis. Supplementary talonavicular

Table 19.1. Preoperative data

	TRP ($n=27$)	STAR ($n=22$)
Age (years)	59.4	61
Weight (kg)	66	63.8
Diagnosis	RA: 23 OA: 4	RA: 16 OA: 6
Gender	Female: 24 Male: 3	Female: 17 Male: 4
Follow-up (years with range)	7.6 (3–12)	2.6 (1–5)

TRP Thompson-Richards prosthesis; *STAR* Scandinavian total ankle replacement.

arthrodesis was performed three times in both groups. In both populations, RA was the main diagnosis, dominating in females.

The distribution of age and weight was comparable in both groups. Table 19.1 shows the details. We had a mean follow-up in TRP of 7.6 years and in STAR of 2.6 years. The responder rate was about 86% (19 ankles) in cementless ankle replacement and 76% (20 ankles) in TRP. Four patients died before examination. We were not able to contact six of the patients.

The follow-up was based on the Kofoed Ankle Score (KAS), which consists of three tests; one subjective, addressing pain and two objective, addressing ankle function and mobility.

19.3 Results

Both populations showed an unacceptable preoperative condition. The total KAS improved in cementless ankle replacement to an average of 86.9 points, corresponding to 94.7% good and excellent results. In TRP, an average score of 77.7 points was achieved at follow-up, corresponding to 75% good and excellent results.

The most benefit was found in pain relief and ankle function. 94.7% of the patients treated with the STAR prosthesis did not have any pain or only slight pain at the start of walking. This aim was only achieved by 60% of the cemented ankle replacements, while 30% of the patients still had occasional load pain. This difference in pain relief is also evident in pain scoring, which increased from 17.7 to 47.8 points in STAR and from 16.6 to 41.9 points in TRP.

The mobility score showed a moderate increase in range of motion (ROM) for extension and flexion in both groups, while a decrease in sub-talar joint movement was noted. This is due to additional sub-talar and talonavicular arthrodesis and secondary arthrosis. The mobility score increased from 12.2 to 13.8 points in TRP and from 12.5 to 14.5 points in STAR replacement. The ROM for extension and flexion increased from a preoperative 27.4° to 37° in TRP and from a preoperative 25.6° to 33.5° in STAR replacement (Figs. 19.1, 19.2).

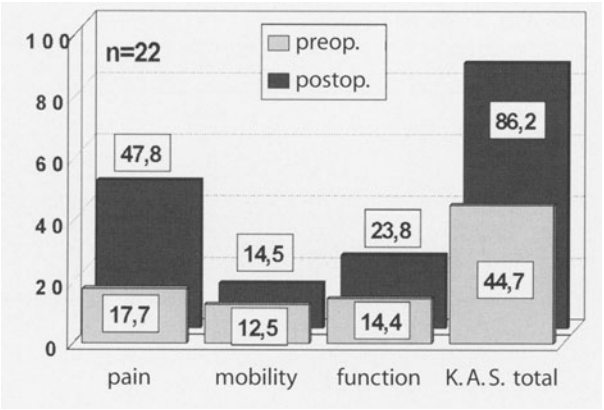


Fig. 19.1. Results in Kofoed ankle score (KAS) for Scandinavian total ankle replacement (STAR)

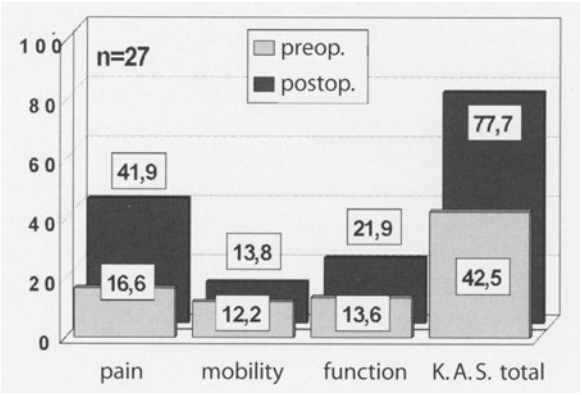


Fig. 19.2. Results in Kofoed ankle score (KAS) for Thompson-Richards prosthesis (TRP)

The radiological examination showed a high rate of radiolucency for the tibial component in the cemented TRP group (53.3%), combined with talar subsidence in three cases. These cases showing progredient, radiolucent lines had to be rated as "implants at risk" and needed further careful control.

Only in three cases (15.8%) of the cementless STAR prosthesis, we found a small radiolucent line, mainly on the flat tibial component. In this group subsidence was not seen at all.

19.3.1 Complications

There were no infections in either population. In TRP ankle replacement, we had two revisions due to prosthesis loosening and one malleolar fracture. In both loosening cases, arthrodesis was performed. The estimated cumulative survival rate at 12 years was 87%. In the STAR prosthesis group, one revision was caused by meniscal breakage. The estimated cumulative success rate at 5 years was 94.3%.

19.4 Conclusion

Though there was a high rate of radiolucency in cemented TRP ankle replacement, with a prosthesis loosening of 7.4%, we achieved good and excellent results in 75% of these. In the STAR prosthesis, only few radiolucent lines could be detected without prosthesis loosening. The total scoring showed good and excellent results in 94.7%. The success of ankle replacement in RA depends on prosthesis design, implantation technique and exact indication. Our study proved the superiority of STAR prosthesis versus TRP design. The advantages of STAR prosthesis are cementless implantation, minimal bone resection and less talofibular impingement due to meniscal load bearing. The correction of hind-foot disorders, by supplementary sub-talar arthrodesis or conservative treatment, is of extreme importance for correct load bearing after total ankle replacement.

The indication for ankle arthroplasty should be restricted to patients with sufficient talar bone stock, intact ligament stability and to those with varus/valgus deviation under 10°.

References

1. Bolton-Maggs BG, Sudlow RA (1985) Total ankle arthroplasty. J Bone Surg (Br) 67B:785–790
2. Clayton ML, Smyth CL (1969) Situation of the foot regarding early synovectomy in RA. Excerpta Medica Amsterdam. 146
3. Hamblen DL (1985) Editorial: Can the ankle joint be replaced? J Bone Surg (Br) 67B:689–690
4. Jensen NC, Kroner K (1992) Total joint replacement: A clinical follow-up. Orthopedics 15:236–239
5. Kaukonen JP, Raunio P (1983) Total ankle replacement in RA: a preliminary review of arthroplasties in 24 patients. Ann Chir gyn 72:196–199
6. Kofoed H, Stürup J (1994) Comparison of ankle arthroplasty and arthrodesis. A prospective series with long-term follow-up. Foot 4:6–9
7. Kofoed H, Danborg L (1995) Biological fixation of ankle arthroplasty. Foot 5:27–31
8. Schemberg F (1997) A European Multicenter study of Cementless Ankle Prosthesis, First International Congress on Ankle Arthroplasty Copenhagen 20–21 June
9. Smith EJ, Ward AJ (1992) Ankle arthrodesis. Foot 2:61–65
10. Teigland CJ (1990) Revisional surgery after failure of total replacement prosthesis of the ankle joint in rheumatoid patients. In Hagena FW, Schwägerl A, Hämäloinen M, Teigland CJ, Revisional surgey in RA. Rheumatology 13:87–91, Karger Verlag, Basel
11. Thabe H (1997) Praktische Rheumaorthopädie. Chapman & Hall 1997
12. Tillmann K, Schaar B (1997) Cemented and uncemented Ankle-EP: Clinical and pedobarographic results. First international Congress on Ankle Arthroplasty Copenhagen 20–21 June
13. Tillmann K (1977) Der rheumatische Fuß und seine Behandlung. Enke Verlag, Stuttgart
14. Vahvanen V (1967) Rheumatoid arthritis in the plantar joints. Acta orth Scand 107
15. Wood P (1997) Total Ankle Replacement (STAR-Link) for Rheumatoid Arthritis. First International Congress on Ankle Arthroplasty, Copenhagen, 20–21 June
16. Wynn AH, Wilde AH (1992) Long-term follow-up of the Conaxial (Beck-Steefee) total ankle arthroplasty. Foot Ankle 13:303–306

CHAPTER 20

Cemented Ankle Arthroplasty for Osteoarthritis and Rheumatoid Arthritis – Long-Term Results*

S. T. SANDBERG · H. KOFOED

20.1 Introduction

It has often been claimed that ankle arthroplasty should be reserved for patients with polyarthritis who have small physical demands. For patients with osteoarthritis (OA), arthrodesis is preferred since arthroplasty may fail rapidly. In the present prospective study, we compared the outcome of ankle arthroplasty in patients with OA and rheumatoid arthritis (RA) on a long-term basis.

20.2 Materials and Methods

During an 8-year period (1981–1989), 52 cemented ankle arthroplasties were performed for either OA patients (25 arthroplasties in 24 patients) or RA patients (27 arthroplasties in 23 patients).

The non-commercial ankle prosthesis designed by one of the authors (HK) consists of either a two-piece device (1981–1985, OA/RA: 12/13) or a three-piece arrangement with a meniscal bearing (1986–1989, OA/RA: 13/14). The configuration of the components was otherwise the same. The prosthesis was congruent with cylindrical movement and allowed for a certain degree of rotation, except in the neutral position where it was stable.

The patients were followed for up to 14 years. The majority of these were followed annually by clinical evaluation according to an ankle scoring system. This system is composed of a pain score, a function score and a mobility score, with a maximum total score of 100 points. The pain score contributed with maximally 50 points (for no pain), the function score with maximally 30 points (for normal daily-life ankle function) and the mobility score with maximally 20 points (for normal mobility and no deformity). Failure of the ankle arthroplasty was defined as revision or arthrodesis.

* This paper has appeared in full in the *Journal of Bone and Joint Surgery*, British volume, 1998 80:328–332

20.3 Results

Nine patients died during the follow-up from causes unrelated to the ankle arthroplasty (Table 20.1). Another 11 arthroplasties were considered to be failures because revision (5) or arthrodesis (6) had been required. The reason for failures can be seen from Table 20.2. Survivorship analysis of the two groups showed no difference, with approximately 75% survival at 14 years.

The 1-year follow-up score values for pain, function and mobility were all significantly improved compared with the preoperative values (Table 20.3).

Table 20.1. Ankle arthroplasties

	Osteoarthritis	Rheumatoid arthritis
Death (*n*)	4	5
Last follow-up, years (range)	5.5 (2–10)	7.5 (3–9)
Lost follow-up (*n*)	1	
Last follow-up (year)	3	
Failures (*n*)	6	5
Years of failure (range)	4 (1–7)	5 (4–9)
Rest (*n*)	14	17
Last follow-up, years (range)	10 (6–14)	8 (6–14)
Total (*n*)	25	27

Table 20.2. Reasons for failure

	Osteo-arthritis	Rheumatoid arthritis	Revi-sion	Fusion	Total loose/not loose
Pain, prosthesis not loose	2	1	1	2	0/3
Tibial component loose	3	3	3	3	6/0
Technical failure	1		1		0/1
Late deep infection		1		1	1/0
Total	6	5	5	6	7/4

Table 20.3. Total ankle score

		Preoperative	Follow-up (years)		
			1	6	10
Osteoarthritis	(*n*)	25	19	16	8
	Median	29	94	94	93.5
	Range	8–47	71–98	71–100	56–96
Rheumatoid arthritis	(*n*)	27	22	18	7
	Median	25	89	85	83
	Range	7–37	77–98	62–98	53–98

Preoperative values refer to all cases. Postoperative values refer to cases without failure.

The improvement was equal for OA and RA, but the preoperative and postoperative scores of function were lower in patients with RA, giving lower total scores for RA.

During the follow-up period, the score values were unchanged for the OA group (Table 20.3). The RA group showed a statistically significant decrease in total score values due to a decrease in mobility score. The decrease was from 89 points at the 1-year follow-up to 83 points at the 10-year follow-up. Clinically, this decrease is probably of no significance.

20.4 Discussion

This is the first prospective study to compare long-term results of ankle arthroplasty used for RA and OA. Contrary to statements in the literature, it showed good long-term results for both the OA and RA group. Eleven cases were considered failures. Six of these had aseptic loosening of the tibial component. One had a late, deep infection after 5 years. In the last four cases, the prostheses were not loose. Five cases were revised and six cases were transformed to arthrodesis. The 14-year survival rate was 75% for both groups. For non-failures in the OA group, the initial improvement in scorings was unchanged during the follow-up. For non-failures in the RA group, there was a tendency for decreasing scores during the follow-up period due to a decreasing mobility score. This seems unavoidable considering the nature of the degenerative disease. The overall findings of the study cast serious doubts to the general restrictive attitude towards ankle arthroplasty and especially towards ankle arthroplasty for OA.

Ankle Arthroplasty and Osteoarthritis

CHAPTER 21

Ankle Arthroplasty – The RAMSES Prosthesis

G. MENDOLIA

21.1 Introduction

Talo-crural arthrodesis may give good short- and middle-term results, especially in osteoarthritis. In the long-term, sub-talar and mid-tarsal arthroses often complicate the results [1–4]. We therefore prefer ankle arthroplasty for some patients. Previous results of ankle arthroplasty have been dubious.

This chapter evaluates the RAMSES prosthesis, which has a spheroid design with multiple axes motion. The four main features of ankle prosthesis that we consider are the intermediate skate, protection of the anterior cortex of the tibia, the lateral edges of the implant and the frontal curve of the talar implant.

21.1.1 The Intermediate Skate

At each step, when the heel touches the ground, a powerful antero-posterior translatory force is exerted on the anterior face of the tibial implant. This weakens the anterior cortex of the tibia and shifts the tibial implant back and down, irrespective of the method of fixation, even for a thick central pin.

21.1.2 Protection of the Anterior Cortex of the Tibia

The anterior cortex of the inferior extremity of the tibia, therefore, acts as a supporting pillar, particularly in one-footed support at footfall, with the foot in the dorsiflexion position. The weakening engendered by cutting an anterior tibial flap results in anterior cortical impaction and in back shifting and de-bonding of the tibial implant.

21.1.3
The Lateral Edges of the Tibial Implant

The implant should maximize restraint, unlike the internal and external malleolar midlines whose function should be minimized. Transversal stability should be ensured by the implant itself through its lateral edges.

21.1.3.1
The Frontal Curve of the Talar Implant

The main tibiotalar movement in flexion/extension is combined with abduction/adduction and pronation/supination movements. The two latter movements occur principally at a sub-talar level, but are also produced, albeit with smaller amplitudes, in the tibiotalar joint. The frontal curvature of the talar implant allows valgus and varus movements with preservation of congruence. Finally, the talar dome will tend to restore global movement at the tibiotarsal joint of the articular complex of the hind foot [5, 6].

21.2
Materials and Methods

The present material consists of 38 RAMSES prostheses (Fig. 21.1A), implanted between 1990 and 1995 in 38 patients (20 females and 18 males). The age at surgery ranged from 40 years to 68 years, with the median 48 years. The follow-up ranged from 2 years to 8 years with the median 4 years and 3 months. The diagnosis can be seen in Table 21.1. The prosthesis can be inserted with or without cement through an anterior straight approach, starting 10 cm above the ankle joint. Fig. 21.1B shows an example of the prosthesis in place (radiograph). A full set of cutting guides is supplied. There were 12 surgeons who performed the cases. At follow-up, the patients' conditions were assessed according to TALUS classification (Table 21.2). Radiographic analysis concentrated on prosthesis position, periprosthetic radiolucency, component subsidence and loosening.

21.3
Results

21.3.1
Perioperative and Postoperative Complications

The complications that arose perioperatively and postoperatively are detailed in Table 21.3.

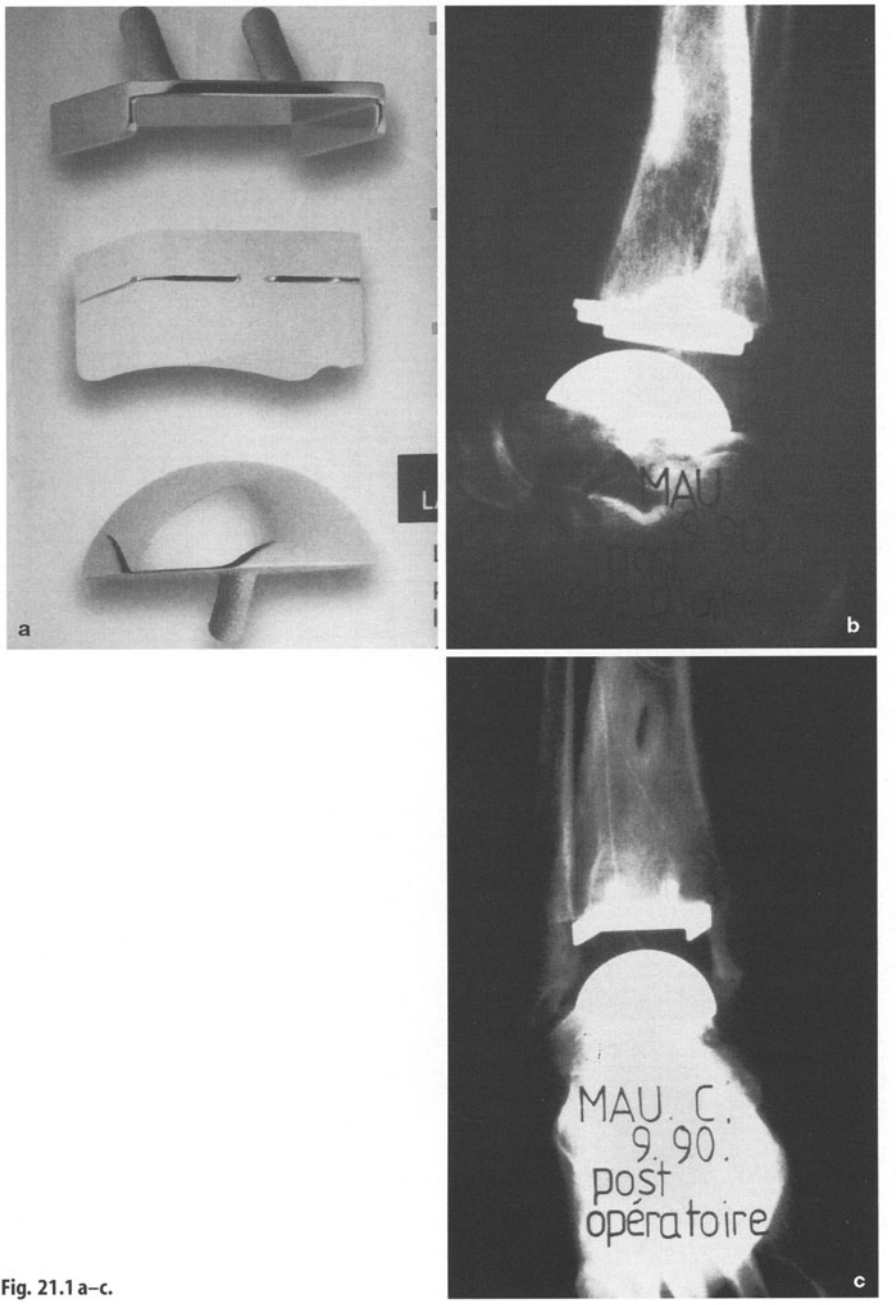


Fig. 21.1 a–c.

Table 21.1. Diagnosis

Osteoarthritis	17
Osteonecrosis	6
Rheumatoid arthritis	7

Table 21.2. Talus' ankle postoperative evaluation (100 points)

Functional results	Notes
Pain	/12
Weight-bearing support	/12
Walking (uneven or flat surfaces)	/43
Stairs	/10
Back-foot position	/1
Shoes	/5
Ankle mobility (dorsiflexion and plantar flexion)	/12
Stability	/5
Conclusion Ankle Functional Value	
Total	/100

Table 21.3. Perioperative complications

	Number
Internal malleolar fractures due to weakening after an attempt to fit an overly wide tibial skate	1
Postoperative complications	
Poor positioning: valgus and varus	3
Ankle instability due to a too thin skate, but without skate displacement	2
Dorsiflexion flaws at the start of our experience. We now apply a wider range of indications for Achilles' tendon lengthening	8

21.3.2 Long-Term Results

During follow-up, five cases were converted to arthrodesis for reasons of pain. Five other cases did not have these satisfactory results because of moderate pain and stiffness (Table 21.4).

21.3.3 Functional Results

Pre- and postoperative statuses were compared with the aid of a check-sheet (Table 21.5).

Table 21.4. Long-term results

	Number
Satisfactory results with a stable and painless ankle not hampering walking or the patient's usual activities	28
Cases (3) in which painlessness was achieved at the price of very marked stiffness, with mobility not exceeding 10° between dorsiflexion and plantarflexion. Cases (2) with moderate pain	5
Cases of considerable pain. Arthroplasties were removed (3 detached prostheses and 2 intact prostheses)	
These secondary arthrodeses gave the following results:	
– 3 acceptable results	
– 2 cases with persistent pain, one of which involved an unfused border	5

Table 21.5. Functional results

Pain	Number
Pain free	20
Pain on loosening up (notably in the forefoot)	8
Weather-related pain	3
Intense pain	7
Weight-bearing support	
Monopodal stability	31
Imbalanced (corresponding to the 7 cases of pain)	7
Walking	
Unlimited	12
Greater than 1 km	20
Less than 1 km	6
Limping	
None	13
Moderate without aid	17
Moderate with occasional use of cane	8
Stairs (climbing and descending)	
Normal	30
Discomfort	6
Holding of banister	1
Negotiation (up or down) of stairs impossible	1
Articular amplitude (overall mobility: dorsiflexion plus plantarflexion)	
40–50°	28
40–30°	3
30–20°	2
Stiffness experienced in the straight position in 5 cases	5
Stability	
Good	28
Chronic instability while walking on uneven surfaces	7
Chronic instability while walking on flat surfaces	3

21.4 Discussion

In all, 38 cases with painful and degenerated ankle joints were treated with the RAMSES ankle prosthesis. In 28 of the 38 cases, the treatment was successful, reaching a pain-free, stable and movable ankle joint. The study also showed some special postoperative complications, i.e. the sub-malleolar syndrome

and the "too-short" Achilles tendon syndrome. Both of these entities can probably be addressed without taking out the prosthesis or revision of its parts.

21.4.1 Sub-malleolar Syndrome

As described by Isbister [7], after the calcaneal fractures, the syndrome covers abnormal contacts between the malleoli, internal or external, with the lateral and medial faces of the talus and the calcaneus. There are various causes of this (fracture of calcaneus, malleolar arthrosis, etc.).

This is often iatrogenic, particularly after ankle arthroplasty, but also after arthrodesis. It is linked to a decrease in the height of the midline by excessive bone resection or by inadequate height of the intermediate skate in arthroplasty. This decrease results in the rising of talus-calcaneal skates in the malleolar pince. Weight bearing is no longer achieved via the prosthesis, but only through direct contact between the malleoli and the medial and lateral faces of the talus and the calcaneus.

A substantial decrease in the sub-malleolar channels leads to marked compression of the tendons between the inextensible aponeurosis and the malleolus itself. This syndrome explains the oedema and sharp malleolar pain noted after certain arthroplasties when the implant is not detached.

It is important to have skates of different heights in order to respect the normal height of the midline. If postarthroplasty pain arises, it should not be ascribed to possible de-bonding and the prosthesis should not be removed. The block can easily be exchanged for a thicker one allowing correct spacing of the sub-malleolar regions. This respect of the midline height results in rejection of direct arthrodesis after ablation of an ankle arthroplasty. Fixation of impacted iliac grafts is preferred and will allow good bone fusion and correct spacing of the sub-malleolar regions.

Arguments suggesting direct arthrodesis after ankle arthroplasty are illusory. Given the minimal thickness of metal and polyethylene implants, this direct arthrodesis is either impossible or dangerous, resulting in pain and in functional impairment due to experimental sub-malleolar syndrome.

21.4.2 Tight Achilles Tendon

During arthroplasty, if there is inadequate dorsiflexion or, worse, if there is fixed equinus, considerable compression forces will develop at the anterior part of the implant during walking and weight bearing. Blocked by a powerful, retracted Achilles tendon, fixed equinus or inadequate dorsiflexion will result in anterior impaction on the tibial implant. This leads to anterior bone lysis and gradual shifting backwards of the implant followed by de-bonding.

Clinically, anterior pain occurs very early, promoted by dorsiflexion of the foot, which reproduces the compression syndrome. If this syndrome does

arise, the Achilles tendon should be lengthened, preferably preventively, if dorsiflexion of 20° is not achieved during fixation of the prosthesis.

21.5 Conclusion

On this basis, we conclude that the RAMSES prosthesis gives good results on pain and range of motion. It represents a viable way of delaying tibiotarsal arthrodesis in certain co-operative patients. Improved understanding of the postoperative pathology of this type of arthroplasty allows us to say that a painful ankle prosthesis may not be detached and should not necessarily be removed.

It is important to understand the problem of a tight Achilles tendon and the painful external sub-malleolar contact, which very often explain the pathology and can be treated specifically and successfully.

References

1. Broquin J, Emani A, Maurer P, Tomeno B (1979) Arthrodèse Tibio-tarsienne; Etude des complications et de la tolérance. Rev Chir Orthop 65:393–401
2. Duquennoy A, Mestdagh H, Tillie B, Stahl P (1985) Résultats Fonctionnels de l'arthrodèse tibio-tarsienne. Rev Chir Orthop 71:151–161
3. Kofoed H, Stürup J (1994) Comparison of ankle arthroplasty and arthrodesis. A prospective series with long term follow-up. Foot 4:6–9
4. Mazur J, Schwartz E, Simon S (1979) Ankle arthrodesis. Long term follow-up with gait analysis. J Bone Joint Surg Am 61:964–975
5. Libotte M, Klein P, Colpaert I, Alameii M, Blaimont P, Halleux P (1982) Contribution a l'étude biomécanique de la pince malléolaire. Rev Chir Orthop 68:299–305
6. Bonnel F, Blotman F (1982) Bases anatomiques et Principes Biomécaniques de la cheville. Cheville et Médecine de Rééducation. Masson éditions, Paris 1–6
7. Isbister JF (1974) Calcaneo-fibular abutement following crush fractures of the calcaneum. J Bone Joint Surg Br 56:274–278

CHAPTER 22

Scandinavian Total Ankle Replacement (LINK S.T.A.R.): Technical Problems and Solutions

H. Huber · R. Kellenberger · M. Huber

22.1 Introduction

Alignment is an established key factor in terms of long-term survival rates in total knee arthroplasty [3]. This is probably also true for total ankle arthroplasty. Especially in young patients with post-traumatic osteoarthritis and hard bone, we encountered technical problems inserting the components with the desired precision. We think that these problems can be solved by some improvements in the instrumentation and we therefore propose some modifications and technical tips we learned during our first 23 cases. Our preliminary results with the Scandinavian total ankle replacement (STAR) are encouraging. We believe that with improvements in the instrumentation, the implantation can be facilitated in some cases and precision would improve.

22.2 Materials and Methods

From 1995 to 1997, 23 STARs were implanted in seven female and 16 male patients by the three above-mentioned surgeons. The age of the patients ranged from 38 years to 82 years, with an average age of 62 years at the time of surgery. We never used cement. Preoperative diagnosis was rheumatoid arthritis in one case, haemophilia in one case, post-traumatic osteoarthritis in nine cases and primary osteoarthritis in 12 cases. Preoperative and postoperative evaluation was carried out with the Kofoed score [2, 4, 5]. Surgical technique and after-treatment were performed as proposed by the designer of the implant [1].

22.3 Results

The mean follow-up in our series is 15 months (3–29 months). We are only reporting about the 12 patients who have a follow-up of more than 1 year.

Five patients present an excellent result with a score of more than 85 points and five others present a good result with a score of more than 75 points. One patient has a fair result and in one case we had to remove the implant and fuse the ankle because of infection and the loosening of the implant.

22.3.1 Technical Implications

We believe that to get good long-term results, the implantation of the prosthesis has to be perfect with regard to the overall alignment and ligamentous balance. The following details of the operation technique are important for its success.

- Alignment of the tibia drill- and saw guide. Correct placement of the guide is of utmost importance to achieve perfect alignment of the axis. Especially in hard bone, there are problems fixing the block in the desired position; sometimes even pre-drilling of the pinholes cannot prevent a certain sliding motion of the block. Corrections are almost impossible if the pins are gliding into the pre-existing holes. We therefore propose a drill- and saw block that can be moved to a certain extent, without having to change pin position once it is fixed stably on the distal tibia. It should be possible to move it proximally and distally to correct the amount of tibial resection (Fig. 22.1). It should also allow some rotation to correct varus/valgus malalignment. By the above-mentioned tool, it would also be possible to re-resect the distal tibia later during surgery, if tension in the joint is too high before the definitive components are inserted. For preoperative planning, it may be useful to get standing antero-posterior and lateral radiographs of the leg.
- Avoid the lateral malleolus. When cutting the first saw cut, it is very important to know the exact location of the distal fibula. In post-traumatic cases, the anterior tibiofibular ligament may be ossified; the visualization of the lateral malleolus is difficult due to post-traumatic malalignment with the lateral malleolus far posterior. If, in addition, the leg is externally rotated on the operating table, the distal fibula might be cut off inadvertently. In order to avoid this complication, one should keep in mind the posterolateral location of the distal fibula. The patient is therefore placed in a supine position with a pillow under the ipsilateral hip to internally rotate the ankle. Every inadvertent osteotomy of the lateral or medial malleolus has to be immediately stabilized by open reduction internal fixation (ORIF). In our 23 cases, we inadvertently cut the lateral malleolus four times. Twice it was immediately fixed by ORIF and the outcome was very good. In two cases, the surgeon didn't realise the osteotomy. One of these cases was the only failure in our series, due to instability of the implant leading to infection and revision with fusion. The other case was immobilised in a plaster cast for a prolonged period of time with, ultimately, a good result.
- Groove for the anchoring fin. Drilling for the anchoring fin of the talar component is easy in soft bone. However, in cases with post-traumatic osteoar-

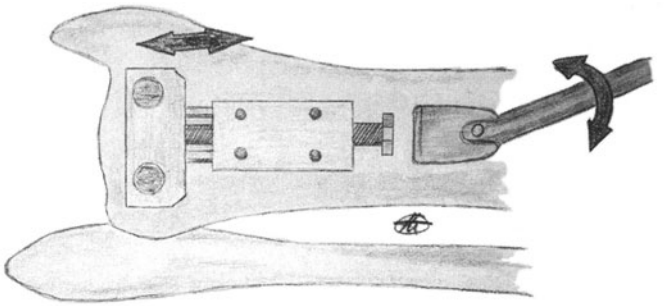


Fig. 22.1. Adjustable drill- and saw block. This modification would allow exact tibial resection as well as re-resection. Varus/valgus correction could be performed with the help of an asymmetrical saw block

thritis and in young patients with rather hard talar bone, difficulties may arise. In order to achieve good stability and stable primary fixation of the fin, the groove should neither be too deep nor too wide. However, if it is not deep and wide enough, it may be impossible to impact the component completely in spite of powerful punches. The result is a malposition of the talar component with too much tension in the joint. This problem could be solved with a trial component that would allow to check the depth of the groove. As an alternative, we propose measuring the depth of the groove with the depth gauge prior to insertion of the definitive component.

- Trial component. Prior to drilling the anchoring holes of the tibial component, which is a definitive step, we think that one should assess the ligamentous tension in the joint with the help of a trial component. This is the last chance to re-resect the distal tibia if there is too much tension in the joint; a problem we encountered in several post-traumatic cases where the posterior capsule and the Achilles tendon may be tight and the normal anatomy distorted. Once the anchoring holes of the tibial component are drilled, higher tibial resection is no longer possible. We therefore propose a tibial trial component that can be anchored on the saw guide (Fig. 22.2). The thickness of this component corresponds to the thickness of the definitive tibial component. Inserted together with the trial gliding core and the talus milling guide, it would allow assessment of the tension and an eventual re-resection of the tibia by means of the above-mentioned adjustable saw guide.
- Holes for the cylindrical anchors of the tibial component. A very important step to achieve stable primary fixation of the tibial component is exact drilling of the holes for the cylindrical anchors. Because of a certain instability of the saw guide, a slight rocking motion of the drill bit is possible and decreases the precision of the anchoring holes, especially in hard bone. Before inserting the definitive tibial component, one should check the correct shape of the anchoring holes, as well as the correct depth. During insertion of the tibial component, we observed in two cases, a malposition of the component that seemed to deviate out of the anchoring holes in the posterior part. The component had to be taken out

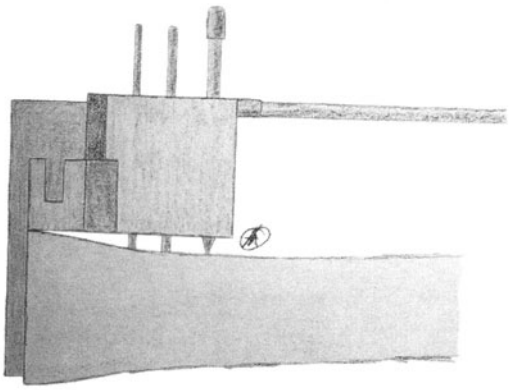


Fig. 22.2. Tibial trial component anchored on the saw block to assess ligamentous tension of the joint prior to drilling of the anchoring holes of the definitive trial component. A re-resection could still be possible with the adjustable drill- and saw block as proposed before

and reinserted again, with a certain loss of primary stability after having re-drilled the anchoring holes in a better position.

- Anterolateral instability. In case of marked varus malalignment or important post-traumatic anterolateral ankle instability, one should be cautious with the indication for total ankle replacement. Once large anterolateral osteophytes are resected, marked instability may result, even in preoperatively stable ankles. Anterolateral stability has to be checked once the definitive or trial components are inserted. If the ankle is unstable, immediate lateral ankle tenodesis must be performed.
- Achilles tendon lengthening. If there is marked shortening of the heel cord due to longstanding equinus deformity or in cases with valgus malalignment of the hind foot and tibialis posterior overload, a gastrocnemius or heel cord-lengthening procedure should be considered in order to increase the extension mobility in the ankle and decrease the stress load on the tibial component–anterior tibial cortex interface.

22.4 Conclusions

Our preliminary experience with the STAR system is encouraging. The main goal is to restore normal alignment of the joint line and the hind foot. Only then can good long-term results be expected. The operation is technically demanding, especially in post-traumatic cases where normal anatomy is distorted and the subchondral bone may be very hard. Especially in these cases, improvements in instrumentation and the consideration of some technical hints may be helpful to get better results.

References

1. LINK S.T.A.R. Totale Sprunggelenksprothese. Broschüre zur Operationstechnik 7:96
2. Garde L, Kofoed H (1996) Meniscal-bearing ankle arthroplasty is stable. In vivo analysis using stabilometry. Foot Ankle Surg 2:137–143
3. Jonsson B, Aström J (1988) Alignment and long-term clinical results of a semiconstrained knee prosthesis. Clin Orthop 226:124
4. Kofoed H, Danborg L (1995) Biological fixation of ankle arthroplasty. Foot 5:27–31
5. Kofoed H (1995) Cylindrical cemented ankle arthroplasty: a prospective series with long-term follow-up. Foot Ankle Int 16:474–479

CHAPTER 23

Our Experience with a Spherical Total Ankle Replacement

A. V. Voegeli

23.1 Introduction

It has been observed that arthrodesis of the ankle is an excellent operation that is well tolerated by patients. However, as Merle D'aubigné [10] indicates, as the medium and long-term results have been analysed, it has been noted that the patients develop arthrosis of the sub-talar and mid-tarsal joints and a tendency to deviation of the hind foot into varus (Fig. 23.1).

The explanation for these facts may be found in the study of the biomechanics of the ankle and tarsus. As Inman [4] indicates, these articulations work jointly. The abolition of the ankle's flexor-extensor movement is compensated by that of the sub-talar. However, the flexor-extensor movement of this forms part of certain more complex movements: those of inversion (plantar flexion, supination, adduction and anterior listhesis of the talus) and eversion (dorsiflexion, adduction, pronation and posterior listhesis of the talus) which, as Orts Llorca [12] indicates, are inseparable; any flexion movement is necessarily accompanied by adduction and rotation. Because the supination is more external (200) than the pronation (100), in the long run, the hind foot deforms into varus.

The idea of replacement of the ankle was suggested in 1890 by a Berlin surgeon by the name of Gluck [3]. Years later, Lelievre [7] proposed arthroplasty by resection; this involves practising a "toilette" of the surface of the talus and osseous resection of approximately 2 cm from the tibial shank. Fully into the era of replacement surgery, Buchholz [1] and Lord [8] published the first results with their ankle replacements in 1973.

In our practise, we began fitting ankle replacements in 1975. In this chapter, we present the results we have obtained and our therapeutic attitude at this moment in time.

23.2 Materials and Methods

The first prosthesis we fitted was the one proposed by Smith [13], which presented two fundamental advantages as far as we were concerned:

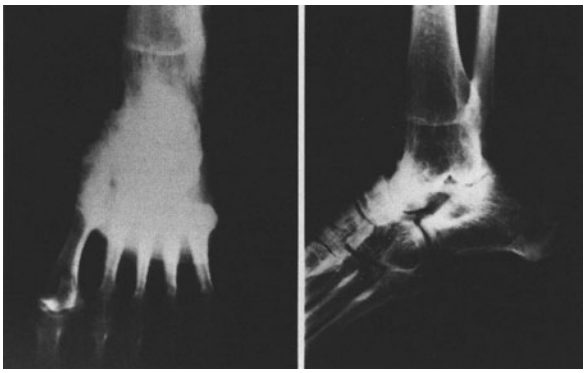


Fig. 23.1. Deformity into varus and peri-astragalar arthrosis as a side-effect of arthrodesis of the ankle

- The ball-and-socket shape of the replacement enables all kinds of movement inside it; it therefore replaces the ankle's flexor-extensor movement and the inversion-eversion movement of the sub-talar. This aspect is fundamental for us, since most of our indications are traumatic sequelae or inflammatory rheumatism, presenting stiffness of the sub-talar joint.
- Bone resection to implant the prosthesis is minimal, whereby, in the event of failure of the surgery, good arthrodesis can always be carried out.
  The Smith replacement, however, had two drawbacks:
  - The concave part is made of metal and the convex part of plastic, although it has been demonstrated biomechanically that the reverse is better.
  - The attachment of the plastic component to the talus is very unstable.

Because of this, in 1984, we began fitting the Bath prosthesis proposed by Kirkup [5]. This, whilst maintaining the ball-and-socket shape, has its concave component in plastic and the convex component in metal and improved attachment to the talus (Fig. 23.2).

The surgical technique used for both replacements is similar, with the ankle being approached from the front, outside the extensor or the toes and the vascular-nervous bundle. The instruments for implantation are specific for each of the replacements, and both have guides for correct alignment of the prosthetic components. Some important facts should be highlighted:

- Neither of the prostheses is self-stable, so the malleolus should be respected.
- The replacement cannot compensate axial deformations of the leg or the foot; this must be corrected prior to fitting the prosthesis.
- When carrying out the bone resection of the rear of the joint, it must be taken into account that the flexor of the Hallux crosses the ankle at this point, and it is very easy to injure it.
- The two components of the replacement need to be cemented.

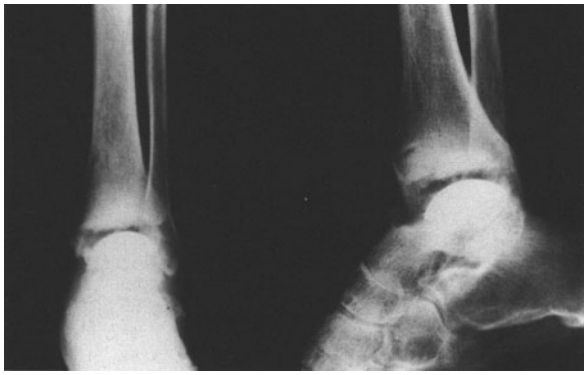


Fig. 23.2. X-rays of Bath ball-type replacement

We have reviewed 40 ankle replacements fitted in 38 patients between 1975 and 1992. The average age of the patients was 40 years, the aetiology of the deformity was: post-fracture arthrosis, 18; talus necrosis, 16; rheumatoid arthritis, 8 (two bilateral cases); and chronic post-instability arthrosis, 2. The replacement type fitted was Smith's [13] in 13 ankles and Kirkup's [5] in 27 ankles.

We have not included, in this review, the group of patients operated on in recent years with the Widhalm replacement [17], which has similar characteristics to Kirkup's, but with improved attachment to the talus, as it has a short follow-up period.

All the patients were subjected to a clinical assessment and an X-ray study of their condition at the time of the review.

23.3 Results

These were assessed according to the parameters shown in Table 23.1. They were: excellent = 0; good = 16; regular = 10; poo = 14. An arthrodesis of the ankle was practised each time on the last group.

23.4 Discussion

We do not consider any result excellent, because the mobility we are given by the ankle replacement is poor, with no case exceeding a value of 200 for plantar flexion and 100 of dorsal flexion; we believe that the latter is due to the stiffness of the syndesmosis as a side-effect of the causal process. This very alteration was encountered by Murray in 1981 [11]. In a gait study on ankle replacements we published in 1986 [15], we noted that the development of the step was very acceptable; we believe that this is due to the replacement of the sub-talar movement made by the design of the replacement we used.

Table 23.1. Results

Excellent results	Mobility over 200	No pain, no edema	Excellent radiological image	Availability for sports
Good results	Mobility close to 200	No pain, no edema	Good radiological image	Incapacity for sports
Regular results	Mobility close to 200	Occasional pain and edema. The intensity doesn't justify reparation	X-rays show loosening of the prosthesis or ossifications around it	Incapacity for sports
Poor results	Severe pain	Loosening or dislocation of the prosthesis	Necessity of arthrodesis of the ankle	

Both Dini [2] and Kirkup [5], in their medium-term studies, assess positively the results of the total ankle replacement, and Kofoed [6], in his 12-year review, finds a 70% survival rate – similar results to those in our series published by Viladot [16]. Overall, we can state that the effect of the total ankle replacement on pain is good.

Takakura [14] defends the uncemented prosthesis. We have no experience of this, although we believe that it is an important problem to be assessed.

At present, the new generation of cylindrical or ball-shaped ankle replacements incorporate an intermediate piece of plastic, which has a shock-absorbing role. The Kofoed [6] replacement should be highlighted in the cylindrical group and the Ramses replacement, proposed by Mendiola [9] should be used in the ball-shaped group. Although the results are encouraging, our experience with both prostheses is very short-lived and, therefore, cannot be assessed at present.

23.5 Conclusions

1. At present, our chief indications are:
   - Patients affected with rheumatoid arthritis – as in a high percentage of cases, the affection is bilateral and the arthrodesis highly invalidating.
   - Traumatic sequelae in patients of advanced age – as the postoperative period of the replacement is much easier than for the arthrodesis and the outlook for survival is good at this age.
2. The type of replacement to use depends on the condition of the tarsus, taking into account the biomechanical reasons set out:
   - If there is affection of the sub-talar: ball-and-socket type replacement
   - If the sub-talar is not affected: cylindrical replacement.

   Both cases use the plastic intermediate element to achieve better shock-absorbency.

References

1. Buchholz H, Engelbrecht E, Siegel M (1973) Total ankle endoprosthesis. St Georg. Mod Chirurg 44:241–244
2. Dini A, Basset FH (1980) Evaluation of the result of Smith total ankle replacement. Clin Orthop 146:228–235
3. Gluck – Quoted by Buchholz [1]
4. Inman VT (1976) The joints of the ankle. Williams Wilkins, Baltimore
5. Kirkup J, Regan MW (1987) The Bath and Wessex ankle arthroplasty. J Bone Joint Surg Br 69:153–154
6. Kofoed H (1995) Cylindric cemented ankle arthroplasty. A prospective series with long-term follow-up. Foot Ankle 16:474–479
7. Lelievre J (1967) Pathologie du pied. Masson et Cie, Paris
8. Lord G, Marotte JH (1973) Prothèse totale de cheville. Rev Chir Orthop 59:239–251
9. Mendolia G, Laroche G, Donneaud B (1994) Biomécanique et cahier des charges de la prothèse de cheville. Med Chir Pied 10:11–14
10. Merle D'Aubigné R (1959) Traumatismes anciens. Rachis membre inférieur. Masson, Paris, pp 424–428
11. Murray WR, Pfeffinger LL, Teasdale RD (1981) Total ankle arthroplasty. J Bone Joint Surg Br 63:459
12. Orts Llorca F (1970) Anatomia human, 4th edn. Cientifico – Médica, Madrid tomo I
13. Smith TW, Elson RA, Hay SM (1993) Long term follow-up of total ankle arthroplasty. The Sheffield experience. J Bone Joint Surg Orthop Proc Suppl 75:297
14. Takakura Y, Tanaka Y, Sugimoto K, Tamai S, Masuhara K (1990) Ankle arthroplasty. Clin Orthop 252:209–217
15. Viladot A Jr (1986) La prótesis total de tobillo: Alternativa a la artrodesis? Chir del Piede 10:61–65
16. Viladot A (1996) Tratamiento de la artrosis del tobillo mediante endoprótesis. Rev Ort Traum 40:389–396
17. Widhalm D (1981) Communication al "Congres de Medicine et de Chirurgie du Piede", Lech on Arlberg, Austria

CHAPTER 24

Medium-Term Results of Cementless Scandinavian Total Ankle Replacement Prosthesis (LINK S.T.A.R.) for Osteoarthritis

H. KOFOED

24.1 Introduction

Treatment of osteoarthritis of the ankle joint has been claimed to be best solved with arthrodesis [1]. This statement solely reflects arthrodesis compared with the results of the first-generation ankle prosthesis which has demonstrated a poor survival. It is also understood that healing of arthrodesis is synonymous with satisfactory clinical results. In a number of smaller series, it has also been claimed that 90% or more of arthrodesis cases with osteoarthritis leads to healing. These statements cannot be tested in an open series of ankle arthroplasty, but such a series can test whether the second-generation ankle arthroplasty with cementless fixation would have medium-term results for osteoarthritis cases that are acceptable.

24.2 Materials and Methods

There were 31 osteoarthritic ankle joints (29 patients) replaced in 1990–1996 by means of a cementless meniscal-bearing ankle prosthesis [Scandinavian total ankle replacement (STAR), Waldemar Link, Germany]. The prosthesis consists of three parts: (1) a metal talus cap which is near anatomical, with flanges to cover the medial and the lateral talus facets; (2) a metal tibial glide plate that is inserted into the subchondral bone of the distal tibia (only the anterior and the posterior edges of the distal tibia are resected); and (3) a polyethylene meniscus between the metal parts. This is congruent towards both metal components. Only compression forces act on the prosthesis. Preoperatively and at follow-up each year, the patients were assessed according to an ankle score system (KAS). This gives a maximum of 50 points for no pain, 30 points for normal daily-life function and 20 points for normal ankle mobility and no deformity. Radiograms were taken under image intensification in order to get compatible and similar views of the ankle. Survival analysis was based on life tables.

24.3 Results

There were 16 males and 13 females in the study. Their median age was 54 years (range 29–79 years).

The diagnosis was primary or secondary osteoarthritis (traumatic). The preoperative score was median 29 (range 6–49). The score at the latest follow-up was median 92 (range 81–99). The radiographic results did not show any signs of prosthesis loosening or subsidence. In all cases, radiating bone sclerosis was found adjacent to the prostheses' components. Survival analysis showed a 96.7% survival rate at 7 years (Fig. 24.1). One case was revised because the tibial component had been inserted in 10° varus (Fig. 24.2).

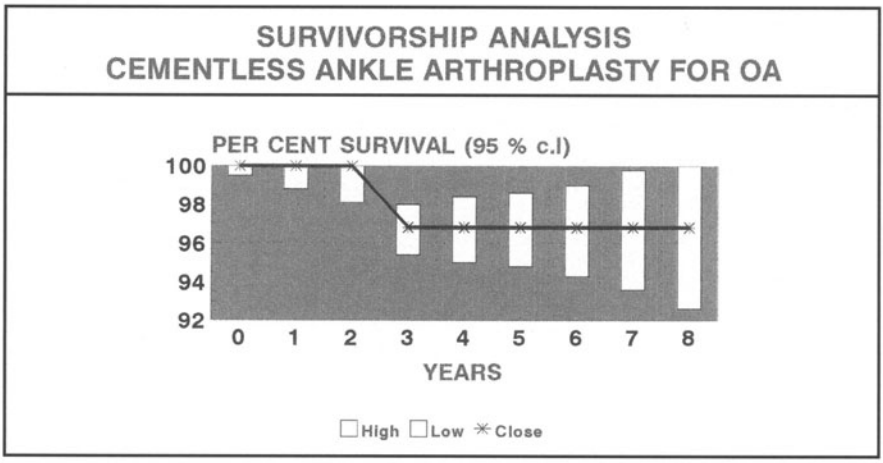


Fig. 24.1. Survival curve for cementless Scandinavian total ankle replacement prosthesis used for osteoarthritis

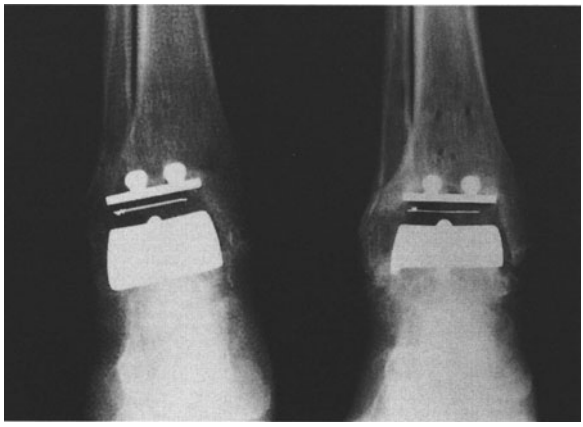


Fig. 24.2. Two years after the primary operation (*left*). Two years after revision of the tibial component to neutral (*right*)

24.4 Discussion

The present medium-term analysis of a cementless ankle arthroplasty used for osteoarthritis cases has shown excellent clinico-radiographic results. The patients have a near normal ankle performance, and radiographic follow-up indicates that the prosthesis components are firmly fixed. It is not conceivable that patients with an arthrodesis would be better off. This is especially true if one does comparisons with large series of ankle arthrodesis [2, 3], where complication rates far exceed the complication rates encountered with second-generation ankle arthroplasty.

References

1. Mazur JM, Schwartz E, Simon SR (1979) Ankle arthrodesis. Long-term follow-up with gait analysis. J Bone Joint Surg Am 61:964–975
2. Lance E, Paval A, Fries I, Larsen I, Patterson R (1979) Arthrodesis of the ankle joint: a follow-up study. Clin Orthop 142:146–158
3. Frey C, Halikus NM, Vu-Rose T, Ebramzadeh MS (1994) A review of ankle arthrodesis: predisposing factors to nonunion. Foot Ankle Int 15:581–584

Instructional Lecture

CHAPTER 25

Arthrodesis of the Ankle

R. A. MANN

25.1 Introduction

Arthrodesis of the ankle was described by Albert in 1879 [2]. The next major advance was the emphasis of compression of the arthrodesis site by Charnley in 1951 [4], four of which contributed to lower rates of non-union. Unfortunately, in the 1970s and 1980s, arthroplasty of the ankle failed to match the success of total joints in other locations. For this reason, arthrodesis of the ankle remains the current treatment of choice for painful arthrosis of the ankle joint.

While there are many techniques used to carry out an arthrodesis of the ankle, in this series, the transfibular approach and fixation with two retrograde 6.5-mm cancellous screws was utilized. An initial report utilizing this technique in 18 ankle joints has previously been presented, and the current chapter represents our further experience with this technique. The patient's age and mobility of the foot were also carefully analyzed, since these factors have not been clearly delineated in the literature [1, 7, 10, 14].

25.2 Materials and Methods

The current study represents a follow-up of patients between January 1990 and January 1995. Review of the patients' charts at the time of their most recent follow-up produced 81 procedures in 77 patients, with a mean follow-up of 35 months (12–74 months). The study included 46 males and 31 females with a median age of 56 years (24–82 years). The most frequent diagnosis was post-traumatic arthrosis in 46, non-union in 12, primary arthrosis in 10, rheumatoid arthritis in 4, and 9 other miscellaneous diagnoses.

The chief complaint was pain in 67 ankles, followed by deformity in 10 and instability in 4. The patients' symptoms were present from 4.5 years to 8.3 years and 75% had tried an ankle-foot orthosis or similar brace for 1 year (6 weeks–15 years).

Radiographic union was stated to occur when osseus trabeculae were present across more than 50% of the joint in all three views [antero-posterior

(AP), lateral and oblique]. At their last follow-up visit, radiographs in the sagittal plane with forced dorsiflexion and plantar flexion were obtained to establish the degree of sagittal plane motion.

25.3 Operative Technique

The procedure was performed through a transfibular approach, with the incision starting approximately 10 cm proximal to the tip of the fibula, and carried distally towards the base of the fourth metatarsal. A full thickness flap of skin was created dorsally and plantarward, through which the distal tibia and ankle joint was exposed anteriorly and posteriorly. Distally, the sinus tarsi and posterior facet of the sub-talar joint were exposed. The fibula was removed approximately 1.5 cm proximal to the ankle joint. A distal tibial cut was made perpendicular to the long axis of the tibia, approximately 2 mm above the dorsal surface of the ankle joint. The foot was placed into a plantigrade position of 0° of dorsiflexion, E-W of valgus, and rotation to match the contralateral side. The proximal portion of the talus was cut parallel to the tibial cut, removing approximately 3 mm of talus. The two flat surfaces were opposed and, if there was any distraction, the medial malleolus was exposed through an anteromedial approach, the deltoid ligament carefully removed from the medial malleolus to protect its blood supply and the distal centimeter of bone removed. The amount of medial malleolus removed depended on the degree of shortening necessary to obtain apposition of the tibia and talus. In some cases with severe post-traumatic deformity, the entire medial malleolus was removed in order to realign the foot under the long axis of the tibia.

Fixation was achieved utilizing two 6.5-mm partially threaded cancellous screws. The arthrodesis site was first stabilized by two 065-K wires, after which one screw was placed in the sinus tarsi area through the neck of the talus and angled as far proximally as possible and through the cortex on the medial side of the tibia. A second hole was placed in the lateral process of the talus as parallel as possible to the first screw and, again, penetrating the cortical surface of the distal tibia.

By placing the screws in this manner, inter-fragmentary compression of the talus against the tibia could be achieved through the cortical purchase of the screws. In four ankles, a third screw was utilized for fixation if the rigidity of the construct at the time of surgery was not deemed to be satisfactory. As a general rule, no iliac-crest bone graft was utilized in this series unless a major reconstructive procedure was undertaken.

The post-operative care included a short-leg, non-weight-bearing cast for 6 weeks and was followed by a short-leg, weight-bearing cast until fusion was complete.

25.4 Results

Fusion occurred in 71 of 81 (88%) ankles, with the average time to fusion being 13.8 weeks (8–50 weeks). Of these cases, 88% were casted for less than 16 weeks.

In the entire series, 10 of 81 (12%) ankles failed to unite. In the subset of patients with an established non-union pre-operatively, 3 of 12 (25%) arthrodeses failed to unite. The average time to union for this group was 22.9 weeks.

Of the ten non-unions that occurred in the series following the index procedure, all healed following a revision that consisted of exposing the non-union site, curetting it and reapplying internal fixation. Of the three non-unions that followed a failed attempt to repair a non-union, one healed with revision, one developed a fibrous union in which the screws were intact and one in a smoker failed to heal.

Patient satisfaction, based on interviews, demonstrated that 70% were satisfied without reservation, 19% satisfied with reservation and 11% were dissatisfied. The reason for dissatisfaction was pain in four, non-union in two, marked limp in one and post-operative wound slough in one.

The physical examination demonstrated that the alignment of the foot was plantigrade in 96% of fusions. The patients were dissatisfied with their alignment because of an attempt made to adjust the hind-foot alignment into varus or valgus at the time of surgery. This was done to create a plantigrade fore foot due to a rigid fore foot varus or valgus deformity. In these cases, despite the fact that the fore foot was in a plantigrade position, the hind foot was in varus or valgus, which dissatisfied these patients.

The overall shortening in the entire series was 9 mm, but when the subset of patients with primary arthrosis was evaluated, their shortening was 4 mm. The average difference in the circumference of the calf was 2.3 cm with the fused side being smaller. The peroneal tendons demonstrated no evidence of subluxation and 82% had a strength of 415 or better. No patient had inversional instability of the hind foot.

The post-operative lateral radiographs obtained in forced dorsiflexion and plantar flexion demonstrated the sagittal arc of motion in the talar first metatarsal to be 24° (9–43%), the talonavicular angle 14° (+1–6°) and the talocalcaneal angle was 8° (+1–60°). Pre-operative radiographs demonstrated arthrosis in the hind foot in 56% of patients with the sub-talar joint being involved twice as often as the talonavicular joint. Of those demonstrating arthrosis pre-operatively, 20% demonstrated progression post-operatively. Three patients subsequently underwent a sub-talar fusion for painful arthrosis.

25.5 Discussion

Currently, the tibiotalar arthrodesis is the definitive treatment for painful arthrosis of the ankle. A solid well-aligned fusion generally results in a pain-

less gait and the functional outcome often exceeds the initial expectations of the patient.

The goals of the operation are to place the foot in a plantigrade position [3, 11] and to obtain a high fusion rate. The primary rate of fusion in our series was 71 of 81 (88%), which compares to the reported average of 66–100% [13, 16].

By utilizing the transfibular approach, excellent visualization of the operative site is achieved, and correction of the non-plantigrade foot was achieved in 96% of the cases. The only cases in which the alignment was unsatisfactory occurred when the surgeon attempted to compensate for a malaligned fore foot by placing the hind foot in a position other than 5° of valgus. It is obvious from the study that the correct alignment of the hind foot should not be sacrificed in order to obtain a plantigrade fore foot; rather, when this situation occurs, the hind foot should be aligned first, after which a fore-foot procedure should be undertaken.

The technique of screw placement that was utilized gives excellent interfragmentary compression, since the screw tips engage the medial-tibial cortex. We believe that this gives better screw purchase than placing them into the body of the talus. Another advantage is that when utilizing this technique, radiographic guidance is not needed since one can observe the entrance point and feel the exit point of each screw. Only rarely is screw removal necessary. Although the distal fibula is removed in the transfibular approach, there were no problems with peroneal tendon subluxation, pain or weakness [12, 15]. The motor function following the procedure was satisfactory in all cases.

The degree of shortening utilizing this approach was minimal. Although the average leg-length discrepancy was 9 mm, this number is somewhat misleading since several patients had shortening due to prior procedures, trauma or both. Those patients undergoing an arthrodesis for primary arthrosis [10] demonstrated only 4 mm of shortening, which probably reflects the true amount of bone loss when carrying out this procedure.

Although special shoes with modified soles or cushioned heels have been recommended after a fusion to protect against impact, at final follow-up, 77% were using regular walking or athletic shoes. The other 23% utilized either a Sach heel or rocker-bottom sole.

Of the 12 ankles in the 11 patients who were treated with the diagnosis of non-union, 9 healed in an average time of 29.9 weeks. This compares with a 54-week time to union in 7 cases treated by Dohm et al. [5] and 21 weeks by Kirkpatrick et al. [8]. Since we carried out the same operative procedure on all patients, but the time to healing was nearly twice that of other patients, we believe that some alteration in blood supply to the bone plays a major role in this delay. Other authors repaired a non-union following an attempted fusion and have utilized bone graft and various means of internal fixation. However, we did not find that bone graft was necessary to obtain fusion. We believe that stimulating the local blood supply by removing fibrous material at the site of non-union and reinserting internal fixation is adequate to obtain union.

Our post-operative radiographs of dorsiflexion/plantar flexion revealed 240 of motion in the sagittal plane, which is similar to that obtained by Abdo and

Wasilewski [1]. This motion occurred almost equally in the sub-talar, transverse-tarsal and remaining mid-tarsal joints.

In our series, we did not observe that greater age correlated to non-union, level of activity, time to union or overall patient satisfaction.

25.6 Conclusion

Arthrodesis of the ankle resulted in significant improvement in function and decreased pain in the great majority of patients in this series. The transfibular approach provides excellent exposure and the ability to place the foot into a plantigrade position. The patients' age did not seem to have any effect on the outcome of the procedure.

References

1. Abdo RV, Wasilewski SA (1992) Ankle arthrodesis: a long-term study. Foot Ankle 13:307–312
2. Albert E (1879) Zur Resection des Kniegelenkes (vol 20). Wien Med Press, Wien, pp 705–708
3. Buck P, Morrey BF, Chao EY (1987) The optimum position of arthrodesis of the ankle. J Bone Joint Surg Am 69:1052–1062
4. Charnley J (1951) Compression arthrodesis of the ankle and shoulder. J Bone Joint Surg Br 33:180–191
5. Dohm M, Purdy BA, Benjamin J (1994) Primary union of ankle arthrodesis: review of single institution, multiple surgeon experience. Foot Ankle Int 15:293–295
6. Holt ES, Hansen ST, Mayo KA, Sangeorzan BJ (1991) Ankle arthrodesis using internal screw fixation. Clin Orthop 268:21–28
7. Jackson A, Glasgow M (1979) Tarsal hypermobility after ankle fusion – fact or fiction. J Bone Joint Surg Br 61:470–473
8. Kirkpatrick JS, Goldner JL, Goldner RD (1991) Revision arthrodesis for tibiotalar pseudoarthrosis with fibular onlay-inlay graft and internal screw fixation. Clin Orthop 268:29–36
9. Kitaoka HB, Anderson PJ, Morrey BF (1992) Revision of ankle arthrodesis with external fixation for non-union. J Bone Joint Surg 74:1191–1200
10. Kitaoka HB, Patzer GL (1996) Clinical results of the Mayo total ankle arthroplasty. J Bone Joint Surg Am 78:1658–1664
11. Mann RA, Van Manen JW, Wapner K, Martin J (1991) Ankle fusion. Clin Orthop 268:49–55
12. Marcus RE, Balourdas GM, Heiple KG (1983) Ankle arthrodesis by Chevron fusion with internal fixation and bone grafting. J Bone Joint Surg Am 65:833–838
13. Maurer RC, Cimino WR, Cox CV, Satow GK (1991) Transarticular cross-screw fixation. Clin Orthop 268:56–64
14. Mazur JM, Schwartz E, Simon SR (1979) Ankle arthrodesis long term followup with gait analysis. J Bone Joint Surg Am 61:964–975
15 Myerson MS, Quill G (1991) Ankle arthrodesis. A comparison of an arthroscopic and an open method of treatment. Clin Orthop 268:84–95
16. Scranton PE (1985) Use of internal compression in arthrodesis of the ankle. J Bone Joint Surg Am 67:550–555

Miscellaneous About Ankles

CHAPTER 26

Long-Term Complications of Ankle Arthrodesis – A Survey

S. T. Hansen

26.1 Introduction

In his description of the evolution of the foot and ankle, Morton described the functional anatomy of the human foot, in which we see both essential and non-essential joints [1]. Bipedal gait created a need for stability in the foot and, in response, the heel has dropped to the ground and the mid-foot and fore foot have widened to provide us with a sturdy, balanced platform on which to walk.

The plantar ligaments under the tarsal and tarsometatarsal joints have consolidated the mid-foot bones (the navicular, the cuboid, and the medial middle and lateral cuneiforms) and the medial three metatarsals into a nearly solid and stable block. As a result, the naviculocuneiform, the intercuneiform, the cuneiform-cuboid, as well as the first, second, and third cuneiform metatarsal joints have become non-essential.

In contrast, the ankle, the sub-talar and the talonavicular joints constitute a functional universal joint to enable the foot to adjust itself to the walking surface and to normal foot and ankle function.

Complex pronation (to cushion weight acceptance) and supination (to make the foot rigid for push-off), using the ankle as a hinge, also takes place in these joints. In theory, then, arthrodesis of one or more of these essential joints would be debilitating to other joints as well as deleterious to normal function. On closer examination, this is certainly the case. Ankle fusion is not an ideal solution, even though this operation has improved function for a legion of patients with severe ankle arthrosis, arthritis and/or deformity.

26.2 Materials and Results

My 30-year experience with foot and ankle surgery indicates that ankle fusion is very helpful during the initial postoperative years, but that symptoms appear in the other "half" of the "universal" joint, i.e., the sub-talar or talocalcaneal joint, after 10±9 years. This joint becomes stressed from overload

while attempting to take over the ankle's job of flexion and extension. Deterioration proceeds rapidly in patients who sustained injury or diseases in the talocalcaneal joint at the outset and in patients who continue to participate in high-impact or high-load activities. This process proceeds much more slowly when the sub-talar joint is initially normal and is treated carefully. A patient's weight and genetic profile no doubt also play a role in determining the speed of onset.

Eventual failure of an arthrodesis, in terms of the limb becoming dysfunctional and requiring further treatment, can be expected in nearly every case. Options open to the patient at that point include marked limitation of activity, use of a brace or, in the worst case scenario, an eventual amputation.

I have seen numerous cases of ankle fusion carried out by others and myself that have resulted, first, in sub-talar fusion, then, in mid-tarsal fusion or bracing. There have also been those who eventually chose to have a below-knee amputation after failure of one or more operations.

This is the natural history of a well-done arthrodesis that has become infected and went on to become non-union. Clearly, ankle arthrodesis is not an easy operation to perform, nor is it uniformly successful in everyone's hands. Certainly this operation is not the "gold standard".

26.3 Discussion

The above findings suggest that, at least in theory, an ankle arthroplasty or total ankle replacement would be a very welcome addition to our orthopedic armamentarium. An ankle arthroplasty would not have to be 100% successful or last indefinitely to be competitive with other operations.

Unfortunately, most attempts in the last 30 years to design and implement a total ankle replacement have been less than successful. This is so well known that many orthopedic surgeons have made up their minds that use of an arthroplasty in this area cannot and will not be successful, i.e. "a joint too far".

I have strongly identified with this group for many years and have not even attempted to use any of the earlier designs. However, as my discontentment with ankle fusion has grown, I have realized that patients are very resistant to ankle fusion and I have become more interested in arthroplasty. In addition, I have read many bioengineering analyses of the theoretical requirements for an ankle-arthroplasty device and formed some opinions of my own with regard to what features a good device should incorporate.

First, an ankle arthroplasty should be of biomechanically sound design. It should bond soundly to bone, maintain the ankle's anatomic alignment and shape, and have incomplete restraint. Second, it should be implanted by surgeons, who understand alignment, ligament balance, and muscle balance in the foot and ankle, and who have the skills to reconstruct them. Alignment of the numerous bones in the foot to the tibia and fibula is clearly somewhat more demanding than alignment of the tibia to the femur.

Both the agility (DePuy) and the Scandinavian total ankle replacement (Link) ankles appear to fulfill the design criteria. It remains for foot and ankle surgeons to devise, learn and teach the analytical and technical skills required for insertion that will produce long-lasting and functional ankle replacements.

References

1. Morton DJ (1935) The Human Foot. 1st Evolution, Physiology and Functional Disorders. Columbia University Press, New York

CHAPTER 27

Bone Mineral Density in the Distal Tibia and in the Os Calcis After Ankle Arthroplasty

B. Zerahn · H. Kofoed · A. Borgwardt

27.1 Introduction

Follow-up radiographs after ankle arthroplasty (AA) usually show an increasing radiating osteosclerosis in the distal tibia just above the tibial component. Because radiographs have poor precision and accuracy in assessing bone mass [1], we have measured bone mineral density (BMD) by means of dual photon absorptiometry (DPA). BMD was measured in the distal tibia bilaterally on patients with ankle arthroplasty (AA) [Scandinavian total ankle replacement (STAR, Link, Hamburg, Germany)]. Also, BMD of the os calcis was measured as an indicator of the loading of the legs.

27.2 Materials and Methods

A prospective group of 11 patients (six females and five males) with unilateral AA and one female patient with bilateral AA had BMD measurements before surgery and after 3 and 6 months. Furthermore, a cross-sectional group of 17 patients (eight males and nine females aged 39–86 years) with previous AA (follow-up period ranged between 9 and 82 months) had BMD measurements once. Paired BMD measurements of the distal tibia and the os calcis were performed with a Gammatec 50, DPA scanner (Gammatec, Denmark). The regions of interest in the distal tibia are shown in Fig. 27.1. For comparing the changes or differences in BMD, the Wilcoxon non-parametric test for paired data was used.

27.3 Results

Before AA, no differences were found between the BMDs of the affected and the unaffected leg. BMD and BMC levels in the distal tibia and the os calcis before and after surgery are given in Table 27.1. During the first three post-

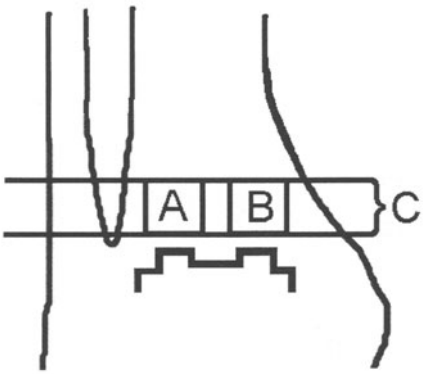


Fig. 27.1. Measurement areas of interest in the distal tibia

Table 27.1. Results of measurement before surgery and at follow-up

	Preoperative values	3 Months	6 Months
Os calcis BMD operated side	0.40 (0.20–0.64)	0.365 (0.20–0.60)	0.40 (0.19–0.57)
Os calcis BMD non-operated side	0.46 (0.28–0.73)	0.435 (0.28–0.74)	0.44 (0.30–0.69)
Region A BMD operated side	0.64 (0.41–1.45)	0.72 (0.58–1.34)	0.85 (0.58–1.50)*
Region A BMD non-operated side	0.65 (0.53–1.02)	0.66 (0.53–1.21)	0.68 (0.51–1.28)
Region B BMD operated side	0.63 (0.25–1.59)	0.64 (0.40–1.38)	0.79 (0.40–1.47)
Region B BMD non-operated side	0.64 (0.27–0.88)	0.63 (0.26–1.07)	0.77 (0.28–1.10)
Region C BMC operated side	2.58 (1.02–7.35)	2.81 (1.24–6.14)	3.29 (1.47–6.61)**
Region C BMC non-operated side	3.12 (1.31–4.37)	3.07 (1.57–5.07)	3.23 (1.16–5.23)

Median values and range for BMC and BMD values of the os calcis and the distal tibia in 13 consecutive ankle arthroplasties, before surgery and 3 months and 6 months post-operatively. BMC values are expressed as g/cm and BMD values as g/cm^2. The p values are given for comparison between pre- and post-operative values, using the Wilcoxon matched-pairs test. *$p<0.05$; **$p<0.02$

operative months, there was a significant decrease in BMD of the os calcis at the operated side (–5.1%, $p>0.05$), whereas no changes were found in BMD of the distal tibia at the same side. After 6 months, BMD in the distal tibia of the operated leg increased in all three regions of interest. Median values of BMD in the distal tibia of the operated leg were 7.5–15.6% higher than the preoperative values.

The patients with previous AA had a significantly lower BMD in the os calcis at the operated side than the non-operated side (–0%, $p>0.05$). However, their BMD in the distal tibia of the operated side was significantly higher than the non-operated side (13.9% in region B and C and 26.0% in region A, $p<0.02$). The differences in BMD between the operated and non-operated leg were not correlated to body weight, gender, ankle score or the primary disease being either arthrosis or rheumatoid arthritis. In the group of patients with previous AA, there was no association between differences in bone mass the operated and non-operated leg, and time after surgery.

27.4 Conclusion

Changes in BMD after AA are consistent with previous radiological findings. A higher BMD of the distal tibia of the operated than of the non-operated leg was found, despite a lower BMD in the os calcis of the operated leg (cross-sectional group). The lower BMD of the os calcis on the operated side may be induced by less loading of the operated leg and/or a decrease in the range of motion of the ankle joint. This was also seen during the first 3 months after surgery, during which the patients wore plaster bandages for 6 weeks. Thus, the stable or higher BMD of the distal tibia of the operated side is most probably induced by the presence of the ankle prosthesis.

The increase in BMD adjacent to the tibial implant is in contrast to the findings of most other arthroplasties, in which a decrease in BMD or a remodelling of bone is common [2, 3]. Because a decrease in bone mass of bone adjacent to arthroplasties is associated with aseptic loosening, we conclude that the increase in bone mass found in patients with AA may be an indirect expression of a well-adapted prosthesis. However, a direct correlation between ankle score and changes in bone mass was not found.

Finally, the study still awaits the results of a follow-up scan 12 months after surgery in the prospective group. The increase in bone mass found in the distal tibia of the operated leg, 6 months after surgery, supports the similar findings in the cross-sectional group regarding a higher BMD in the distal tibia of the operated leg after AA.

References

1. West JD, Mayor MB, Collier JP (1987) Potential errors inherent in quantitative densitometric analysis of orthopaedic radiographs. A study after total hip arthroplasty. J Bone Joint Surg Am 69:58–64
2. McCarthy CK, Steinberg GG, Agren M, Leahey D, Wyman E, Baran DT (1991) Quantifying bone loss from the proximal femur after total hip arthroplasty (comments). J Bone Joint Surg Br 73:774–778
3. Petersen MM, Lauritzen JB, Pedersen JG, Lund B (1996) Decreased bone density of the distal femur after uncemented knee arthroplasty. A 1-year follow-up of 29 knees. Acta Orthop Scand 67:339–344

CHAPTER 28

Comparison of Five Different Scoring Systems for Ankle Arthroplasty*

N. Levi · H. Kofoed

28.1 Introduction

There are a number of ankle rating systems used for evaluating results of ankle arthroplasty. Many of these, however, are based on different concepts and may be expected to give divergent results. The aim of this study was, therefore, to compare five of the more commonly used ankle rating systems.

28.2 Methods

The five assessment systems investigated were the Evanski et al. score system (1977), the Mazur et al. scoring system [6], the Kofoed ankle score [5], the Buechel et al. score [2], and the Kitaoka et al. [4] score system. The relative weight given to pain, function and mobility was compared. Also, the relationship between the severity of symptoms and the given score was compared for all five systems.

A total of 24 patients (14 females and 10 males) suffering from osteoarthritis (8 cases), rheumatoid arthritis (15 cases) and 1 talus necrosis were assessed. The patients mean age at the latest follow-up was 69 years (range 55–91 years) and the mean follow-up was 9 years (range 7–14 years). The preoperative and the latest ratings were performed from a general database including all the parameters contained in the five different scoring systems. The ankle score could then be compiled for each of the systems. The relationships among the relative weighting given to a symptom level or various measurements of function was also analysed for all five rating systems.

* This paper has been accepted as a full paper for publication in *Foot and Ankle Surgery*

28.3 Results

All five systems have a maximum score of 100 points. The relative weight given to pain, function and mobility/deformity, as well as the mean preoperative and follow-up scores are given in Table 28.1. Also the preoperative to follow-up ratio for the 24 patients is shown.

Estimation of the error due to discontinuity in the scoring scale: an ankle scoring scale can be considered as a function of many variables, such as pain, walking distance, range of movement, etc. As an approximation, we may look on them as independent variables. The total errors in measurement can be calculated from the formula:

$$dE = (dE/dx)\,dx + (dE/dy)\,dy + (dE/dz)\,dz + \ldots .$$

In our case, dE/dx reduces to 1, and dx is the error of measurement of the first variable. A similar argument can be used for the other variables. For example, if mild pain gives 30 points and moderate pain gives 20 points, and no intermediate grading exists (pain quality between mild and moderate), then the error of measurement is ±5 points. Also, if, for instance, mild limp gives 3 points and moderate limp gives 1 point, the error of measurement is ±1 point. The total error for these two variables is thus ±6 points. The result of adding all similar errors for each of the five scoring systems is given in Table 28.2, which seems to indicate that all the scoring systems are rather inaccurate.

Table 28.1. Ankle scoring systems. Distribution of weight paid to pain, function and mobility/other [2–6]

	Evanski	Mazur	Kofoed	Buechel	Kitaoka
Pain	40	50	50	40	40
Function	50	40	30	40	28
Mobility/other	10	10	20	20	32
Total	100	100	100	100	100
Mean for 24 cases					
Preoperative	28	26	20	31	30
Follow-up	78	79	82	79	79
Follow-up/pr eop. score					
Ratio	2.8	3.0	3.9	2.6	2.6

Table 28.2. Total error due to discontinuity in scoring scale

Evanski [3]	(1977)	±16 points
Mazur [6]	(1979)	±15 points
Kofoed [5]	(1986)	±26 points
Buechel [2]	(1988)	±16 points
Kitaoka [4]	(1994)	±26 points

28.4 Discussion

Rating systems have many imperfections. The relative weight given to a symptom or measurement is arbitrary in most cases. Many of the variables are not independent. The estimation of error during measurement and compiling of a score may suggest a low reproducibility. However, four of five systems gave almost identical preoperative values, and all five systems gave nearly the same follow-up scores. One of the systems, the Kofoed score, gave a much higher preoperative/follow-up ratio than the other systems. This was due to a more harsh preoperative scoring. However, this has no practical advantage. We cannot point to any real advantage or disadvantage for any of the five systems from a general point of view.

We have failed to demonstrate any rationale for the different weighting of pain, function and mobility in the systems. We have also failed to find any specific areas of application or certain foot problems that justify the differences in the five scoring systems. The validity of a point system is open to criticism because the weighting of the various qualities is a matter of opinion. The question of whether to include function in a rating system is also debatable since other medical conditions may reduce a person's functional capacity [1]. Our results suggest that any of the current point systems may be used to score ankle arthroplasty. On the other hand, there seems to be no justification for these complicated scoring systems, when a much simpler system with only two or three questions giving a total score of 10 points would be as accurate. A simpler universal international score is desirable.

References

1. Binazzi R, Soudry M, Mestriner LA, Insall JN (1992) Knee arthroplasty rating. J Arthroplasty 7:145–148
2. Buechel FF, Pappas MJ, Iorio LJ (1988) New Jersey low contact stress total ankle replacement: biomechanical rationale and review of 23 cementless cases. Foot Ankle 8:279–290
3. Evanski PM, Waugh TR (1977) Management of arthritis of the ankle. Clin Orthop 122:110–115
4. Kitaoka HB, Alexander IJ, Adelaar RS, Nunley JA, Myerson MS (1994) Clinical rating systems for the ankle, hindfoot, midfoot, hallux and lesser toes. Foot Ankle 15:349–353
5. Kofoed H (1986) A new total ankle joint prosthesis. In: Kossowsky R, Kossovsky N (eds) Material sciences and implants in orthopedic surgery. Martinus Nijhoff, NATO ASI series E: Applied Sciences 116, Dordrecht, pp 75–84
6. Mazur JM, Schwartz E, Simon SR (1979) Ankle arthrodesis. J Bone Joint Surg Am 61:964–975

CHAPTER 29

Patients' Visual Analogue Ankle Scoring

A.L. Jensen · H. Kofoed

29.1 Introduction

Numerous scoring systems have been developed to estimate the success rate of different surgical procedures. These scoring systems are created by physicians. The systems are often made with little regard for the goals and desires of individual patients [1, 2]. Most of the existing scales have not been thoroughly tested for reliability and validity [3]. The aim of this study was to analyse a patient-based severity-importance rating and compare this with the physician-based rating, Kofoed ankle scoring (KAS) [4].

29.2 Patients and Methods

Nine consecutive painful and degenerated ankle joints in eight patients were treated within 1 month with a cementless ankle arthroplasty [Scandinavian total ankle replacement (STAR), Waldemar Link, Germany]. Four males and four females were treated. Their median age was 60 years (range 50–73 years). The diagnoses included six cases with osteoarthritis (six replacements) and two with rheumatoid arthritis (three replacements). The patients filled out questionnaires preoperatively and again at follow-up after 3 and 6 months. They noted weight gain, pain, function and mobility, respectively, using a maximum of 100 points. Furthermore, they rated their individual situations on visual analogue scores (VAS) for pain, function and mobility. The VAS scale was 100 mm. The worst outcome was 0 mm and the best 100 mm (100%). Finally, they were assessed according to KAS. This KAS evaluation took place preoperatively and again at a 6-month follow-up. This was compared with the patients' opinions. The KAS values were calculated as percentages in order to compare them with VAS, e.g. for KAS pain equal to 15/50; the percentage equals 30%. For statistical analysis, Kendall's and Spearman's test for non-parametric correlations were used [5].

29.3 Results

Table 29.1 shows that the patients' importance ratings change with time. A comparison of VAS with KAS can be seen from Table 29.2. The values presented are given as percentages of maximum, i.e. the best outcome. The p values represent a 95% confidence limit. We found no significant correlation of VAS with KAS, except for postoperative pain rating. In order to find out whether patients could distinguish among the three qualities, analysis of interdependence for VAS pain, function and mobility were tested. The correlation analysis (Kendall), $p<0.01$, showed a significant correlation between function and mobility scores. Pain scores were not correlated to any of the other qualities ($p>0.061$). Analysis of the KAS values showed no correlation ($p>0.052$). Table 29.3 shows the comparison of weighted total scores (VAS × patients' importance rating) and total KAS scores. No correlation was found among the total scores.

Table 29.1. Patients' importance ratings compared with Kofoed ankle score (median values and range)

	Pain	Function	Mobility
Preoperatively	30 (0–50)	40 (25–100)	30 (0–40)
3 month	40 (20–75)	40 (25–60)	20 (0–40)
6 month	40 (10–60)	30 (20–70)	30 (15–50)
KAS (fixed)	50	30	20

Table 29.2. Visual analogue scores (VAS) compared to KAS (Kofoed ankle score points correlated to VAS). Median values (range)

	VAS Preoperative	KAS Preoperative	p (0.05)	VAS 6 months	KAS 6 months	p (0.05)
Pain	29 (23–63)	30 (0–30)	0.166	90 (20–100)	100 (70–100)	0.018*
Function	33 (17–87)	50 (0–80)	0.825	80 (45–100)	90 (40–100)	0.594
Mobility	28 (7–89)	55 (35–70)	0.311	66 (40–100)	90 (80–100)	0.930

* Statistically significant

Table 29.3. Importance of weighted total scores compared with Kofoed ankle score (KAS) total scores. Median (range)

VAS Preoperative	KAS Preoperative	p (0.05)	VAS 6 months	KAS 6 months	p (0.05)
30 (19–68)	27 (23–53)	0.362	75 (52–100)	90 (76–100)	0.283

VAS visual analogue score

29.4 Discussion

Ankle scoring systems are based on arbitrary units [4, 6]. None of the available systems operate with patients' estimations [1]. We have tried to compare a patient-based scoring system with a physician-derived scoring system. Generally, the results showed no correlation between the two systems. When constructing a scoring system, the issues considered include what qualities will be incorporated and how important each quality should be, i.e. how much weight it should be given out of a total score. Physician opinion differs regarding which symptoms and findings should be included in a scale and how to rate their relative importance [3]. In KAS, the qualities have fixed weights. This weighting is an estimate of the physician's opinion of the relative importance of each of the qualities. No concern is given for the patients' opinion regarding which quality to evaluate and how much weight each quality should carry [1, 7]. In contrast to this very rigid system, the patient importance rating seems to be constantly changing, reflecting that their own clinical status differs with time.

In our experience, it is mandatory that the patients fully understand the meaning of each quality in order to rate them. Some qualities (function and mobility) seem so closely related that patients have problems in the rating process. The VAS may seem to be an easy and reproducible method in estimating clinical outcome, but its reproducibility only seems related to pain quality [2]. If the patient does their own scoring, the possibility of physician bias is minimised [8]. The more objective qualities are function and mobility. In the physician's vocabulary these are related to specific abilities and measurements, which seems to create a problem for the patients evaluating a VAS. It seems more appropriate to evaluate mobility in an objective manner, e.g. radiographs and function on an index based on abilities (e.g. one-leg stand) [1]. Each ability should be given the same weighting in contrast to the schematic scoring system, where abilities have different weightings [1].

29.5 Conclusion

In our study, it seems there is no correlation between patient-based evaluation of clinical outcome and the physician-based scoring system. A scoring system should be based on subjective and objective measurements. Strictly subjective qualities, such as pain, may be evaluated on VAS. Objective qualities may be evaluated on measurements and ability indexes without any arbitrary scoring values. This pilot study will be followed up in a larger series, where statistical analysis will test the strength of the observations made in this study.

References

1. Feinstein AR, Josephy BR, Wells CK (1986) Scientific and clinical problems in indexes of functional disability. Ann Intern Med 105:413–420
2. Wright JG, Rudicel S, Feinstein AR (1994) Ask patients what they want. J Bone Joint Surg Br 76:229–234
3. Wright JG, Young NL (1997) The patient-specific index: asking patients what they want. J Bone Joint Surg Am 79:974–983
4. Kofoed H (1995) Cylindrical cemented ankle arthroplasty: a prospective series with long-term follow-up. Foot Ankle Int 16:474–479
5. Siegels S (1988) Non-parametric statistics for behavioural science, 2nd edn. McGraw-Hill, New York
6. Kitaola HB, Alexander IJ, Adelaar RS, Nunley JA, Myerson MS, Sanders M (1994) Clinical rating systems for the ankle, hindfoot, midfoot, hallux and lesser toes. Foot Ankle Int 15:349–353
7. O'Doherty D (1994) The foot and ankle. In: Pyinont P, Fairbank J, Carr A (eds) Outcome measures in orthopaedics. Butterworth Heinemann, London 12:245–268
8. Gartland JJ (1988) Orthopaedic Clinical Research. Deficiencies in experimental design and determinations outcome. J Bone Joint Surg Am 70:1357–1364

CHAPTER 30

Radiographic Passive Mobility of Ankle Joints Before and After Ankle Arthroplasty

T. ELGAARD · H. KOFOED

30.1 Introduction

The advantage of ankle arthroplasty over arthrodesis is the mobility of the ankle joint and, therefore, a more normal gait. Only one study has previously measured the mobility in the prosthetic ankle joint [1]. This was performed postoperatively after a median time of 39 months.

30.2 Materials and Methods

There were 11 consecutive ankle arthroplasties for 10 patients who were preoperatively measured clinically and radiographically for total passive ankle motion, as well as for dorsiflexion and plantar flexion.

The radiographic measurements were taken from radiograms with the foot in maximal dorsiflexion and maximal plantar flexion (passive). The axes used for the calculations were: (1) the long axis of the tibia in the lateral view, and (2) an axis between the middle of the talonavicular joint and the posterior process of the talus (Fig. 30.1). The radiographic procedure was performed by radiographers. Measurements on the radiograms were performed by a radiologist who was not aware of the patients' clinical situations.

The clinical measurements were performed between the long axis of the fibula and a line between the base of the fifth metatarsal and the plane of the heel during active dorsiflexion and active plantar flexion.

There were five males and five females (one bilateral case) with a median age of 57 years (range 49–72 years). There were seven ankles with osteoarthritis and four with rheumatoid arthritis. The prosthesis was Scandinavian total ankle replacement (STAR) (Waldemar Link, Germany). Measurements were repeated with the same set-up 6 months postoperatively.

30.3 Results

The measurements on the radiograms were repeated with intervals. It was found that the median intraobserver difference was 1° (range 0–3°).

The median radiographic total range of motion, preoperatively, was 16° (range 13–50°). The median clinical total range of motion, preoperatively, was 30° (range 0–35°). At the 6-month follow-up, the total radiographic motion was 22° (range 15–36°). There was no significant correlation among any of these parameters. The gain in radiographic dorsiflexion, median 7° (range 4–21°), was significant, whereas the change in plantar flexion, median 3° (range 15–4°), was insignificant. In Table 30.1 the radiographic and clinical measurements are compared. Figure 30.2 shows the result at follow-up of the case shown in Fig. 30.1.

30.4 Discussion

The way of defining the axis in an ankle joint before and after implantation of a prosthesis may not be easy. We chose to use the long axis of the tibia in

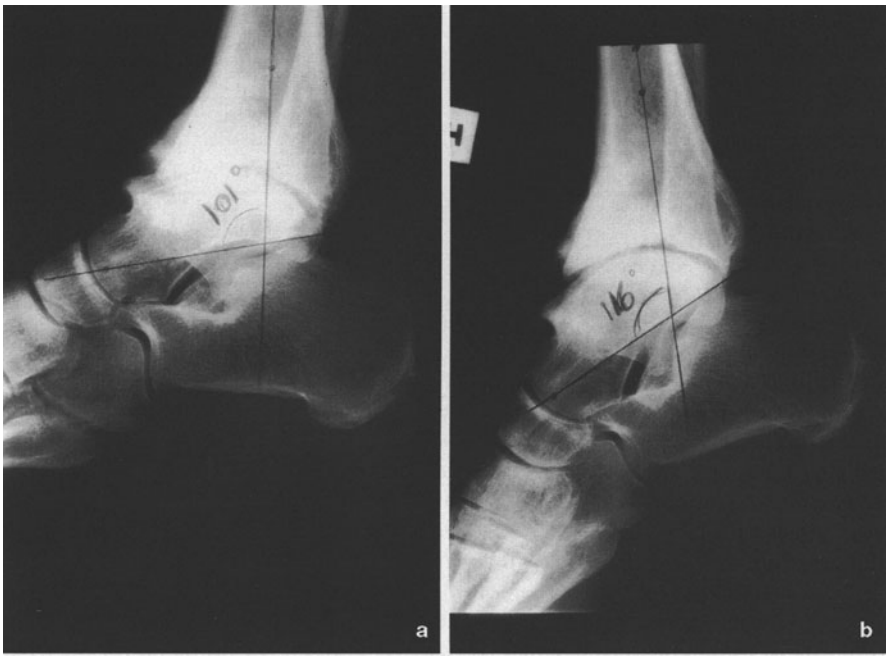


Fig. 30.1 a, b. The preoperative radiographs in dorsiflexion and plantar flexion. The axes used for measurements are indicated. Total range of motion is 15°

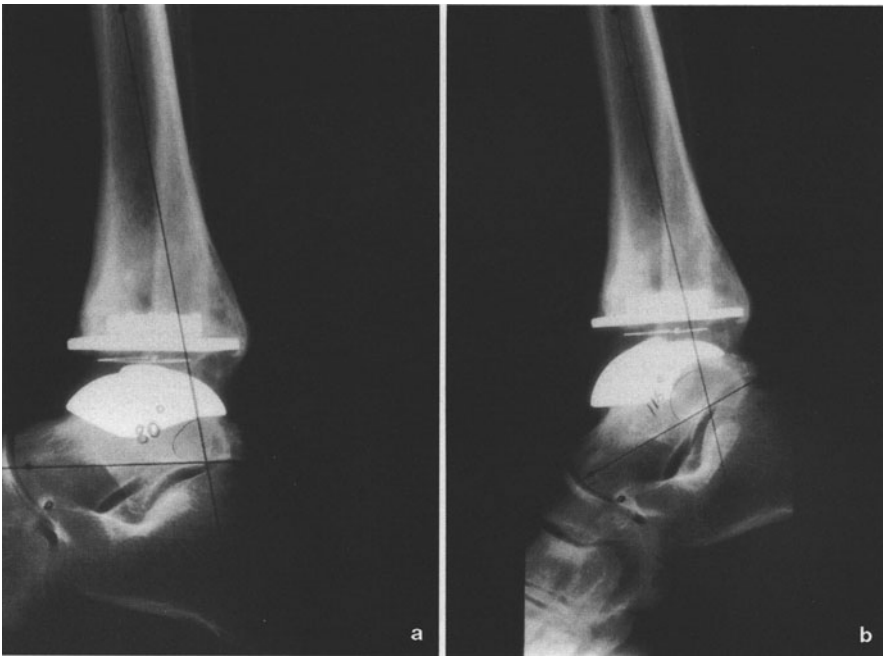


Fig. 30.2 a, b. The same patient's radiographs at follow-up. The same axes are used. Total range of motion is 36°

Table 30.1. Comparison of radiographic and clinical measurements

Total range of motion	Preoperative		*p*	Follow-up		*p*
	Radiograph	Clinical		Radiograph	Clinical	
Median	16	25	0.02	22	40	0.02
Range	13–50	0–35		15–36	40–50	

the lateral view as one axis. The other axis was artificial, but was chosen because it can be identified accurately on both preoperative and postoperative radiograms. The neutral axis in the ankle joint was defined as a line perpendicular to the tibia axis. From this axis, it is possible to measure, rather accurately, the true passive movement in the ankle joint. That there was no correlation between the radiographic measurements and the clinical measurements is not surprising [1, 2]. It is well known that other joints' mobilities add to that of the ankle joint. Furthermore, it is not possible clinically to estimate the neutral position of the ankle joint. This makes radiographic measurements important to judge the true motion in the ankle joint. Although these measurements were performed passively, they give information on what can be gained in ankle mobility after ankle arthroplasty. Curiously enough, the median total range of motion in the present study was similar to that

measured radiographically for another prosthesis [1]. However, the range of dorsiflexion was better in our study. All of their patients suffered from rheumatoid arthritis. They found a radiographic total range of motion of 18°. Clinical measurements were performed preoperatively and at follow-up. They showed 45° preoperatively and 25° at follow-up. We think that this was most likely caused by stiffening in adjacent joints and not necessarily by reduced motion in the ankle joint. From our results, it seems that the greatest advantage is the gain in dorsiflexion. This is what has an impact on the gait.

References

1. Sinn W, Tillmann K (1986) Mittelfristige Ergebnisse der TPR-Sprunggelenks-endo-prothese. Akt Rheumatol 11:231–236
2. Backer M, Kofoed H (1989) Passive ankle mobility. Clinical measurement compared with radiography. J Bone Joint Surg Br 71:696–698

Instructional Lecture

CHAPTER 31

Instructional Lecture. Can the Ankle Joint Be Replaced? Yes

H. KOFOED

31.1 Introduction

The literature on ankle replacements includes many statements, none of which have been subjected to comparative analysis. They are based on results of the first-generation ankle prosthesis. These had several things in common: they did not respect normal ankle kinematics, they used rather large bone resections, they changed the level of the ankle axis, and they were unable to correct angulations in the ankle joint to any significant degree. The mediocre outcome of most of these efforts led the orthopaedic community to abandon ankle replacement. This was firmly expressed in an editorial asking "Can the ankle joint be replaced?" [1] and in another paper titled "Ankle prosthesis: a joint too far" [2]. The time has come to challenge this concept. On the basis of more than 100 consecutive cases of ankle arthroplasty in a prospective series, with up to 15 years follow-up, it is possible to analyse the most frequent sayings about ankle arthroplasty. Some of the previous papers given during this congress have already answered some questions and I shall only briefly repeat their conclusions.

31.2 Frequent Sayings

31.2.1 "Ankle Arthroplasty Does Not Work in Younger Persons"

We have looked at the first 100 cases with osteoarthritis (OA) and rheumatoid arthritis (RA). There were 30 patients under the age of 50 years and 70 patients who were 50 years or older. The median age of the first group was 43 years (range 22–49 years) and for the second group was 64 years (range 51–83 years). The median follow-up time was 7 years (range 1–15 years) for both groups. The distribution of OA and RA was the same (Table 31.1).

Failures were defined as exchange operation (for whatever reason) and secondary ankle arthrodesis. Table 31.2 shows the distribution and reasons

Table 31.1. Results of ankle arthroplasty in younger persons. Comparison of groups older or younger than 50 years

	No. of cases	Diagnosis	
		OA/RA (%)	Male/Female (%)
<50 years	30	60/40	47/53
>50 years	70	61/39	44/56

Table 31.2. Reasons for failures

	30 Cases <50 years of age	70 Cases >50 years of age
Pain (prosthesis not loose)	1 F	1 C, 2 F
Aseptic loosening tibial component	1 C, 1 F	2 C, 1 F
Technical failure	–	2 C
Late deep infection	1 F	–
Time to failure	5 years (range 5–9 years)	5.5 years (range 2–8 years) n.s.
No. of failures	4/30	8/70 n.s.

C, change; *F*, fusion

for failure in both groups. Comparative survivorship analysis did not show any significant difference. As with any other artificial joint, younger persons should be aware that vigorous sports are not compatible with an ankle arthroplasty if it is expected to last.

These results do not support the general fear of implanting ankle prosthesis in younger persons.

31.2.2 "Ankle Arthroplasty Works Best in Rheumatic Patients"

In comparing pain, function and mobility in patients with RA and OA on a long-term basis, as in the paper by Kofoed and colleagues [3], it was demonstrated that there was virtually no difference between OA and RA cases. Cases with OA seemed to have the straightest course, whereas cases with RA had a slightly decreasing mobility throughout the years. The pain relief was the same for both groups.

With such results, there is no reason for not also treating OA cases with ankle prosthesis.

31.2.3
"Ankle Arthroplasty Survives Better in Rheumatic Patients"

From the same prospective series as in Chapt. 20, it was found that the survivorship analysis using life tables gave no significant difference between cases of OA and RA at a 15-year follow-up.

There is no reason for reserving ankle prosthesis for RA cases only.

31.2.4
"Ankle Prosthesis Cannot Correct More than 10° Angulation"

With the special sculpturing technique that has been described by Kofoed [5], it has been possible to correct considerable angulation of varus or valgus. Figure 31.1 a–e illustrates an example. Figure 31.2 illustrates that these corrections usually hold their position and shows correction in cases of RA, where these deformities are most frequently seen.

Ankle arthroplasty can correct and hold large deformities.

31.2.5
"There is no Reason to Believe Cementless Implantation Should Give Better Results in Ankle Arthroplasty"

Considering the difficulty in cementing tibial prosthesis components and the risks of getting extruding cement into the rather small joint space, it could theoretically be an advantage to perform cementless ankle arthroplasties. We have, in a comparative study (see Chapt. 10), shown that cementless prostheses do grow in and that at a 7-year follow-up have a significantly higher survival rate than the cemented version of the same prosthesis.

Ankle prostheses should be uncemented.

31.2.6
"Ankle Arthrodesis Gives Better Results than Ankle Arthroplasty and is the Treatment of Choice"

There is only one published comparative study on ankle arthrodesis versus arthroplasty [3]. It demonstrated a median follow-up for both groups of 84 months (range 58–120 months). The groups were compared on an ankle scoring system where points for mobility were omitted. Both pain score and function score were significantly better for the group with ankle arthroplasty.

Ankle arthroplasty should be the first choice. Arthrodesis should be reserved for failures and contraindications.

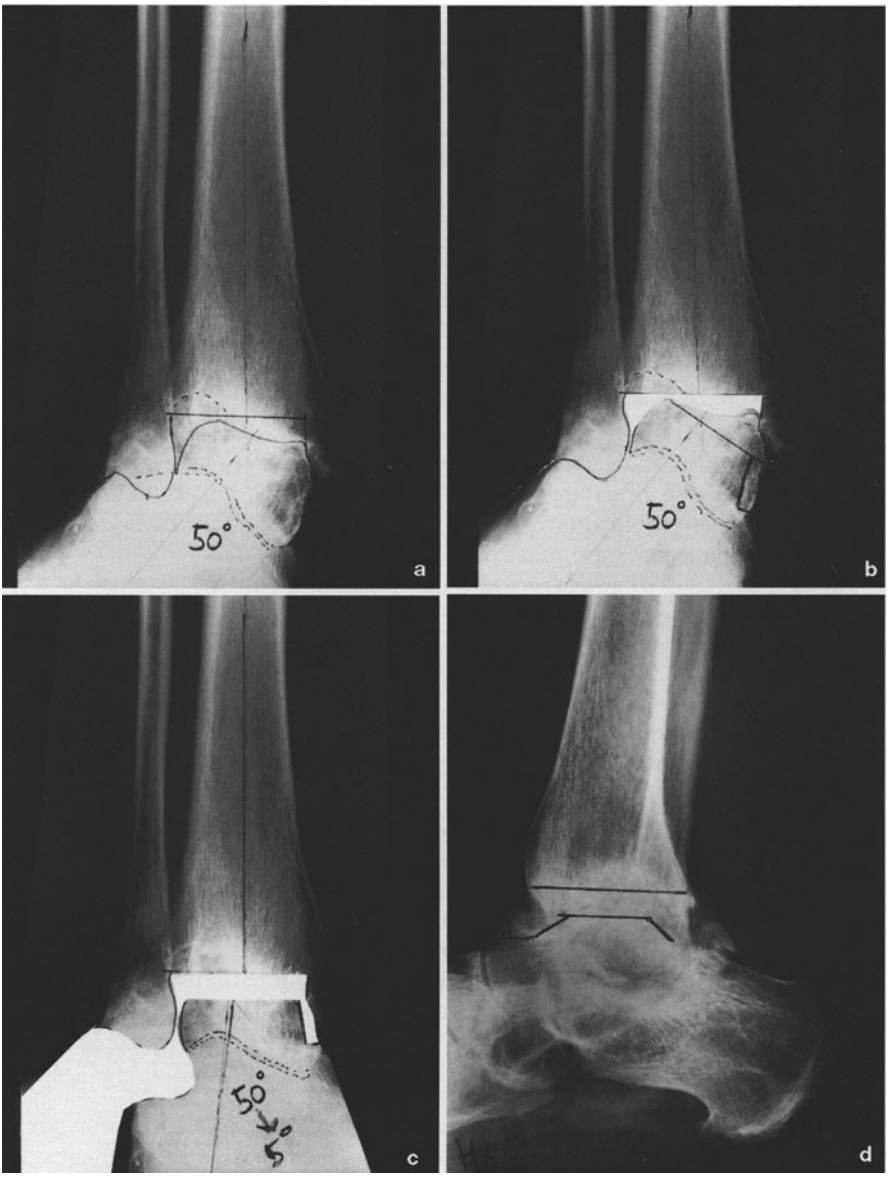


Fig. 31.1a–d

Fig. 31.1 e

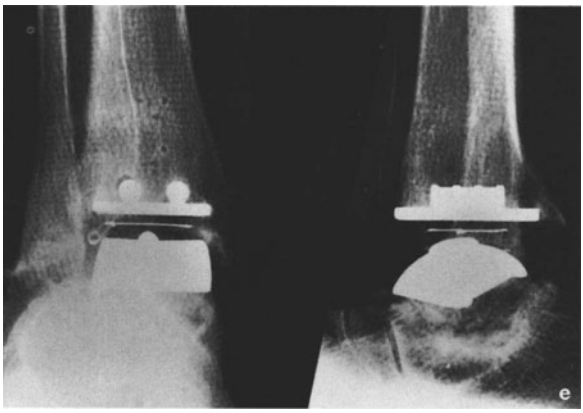
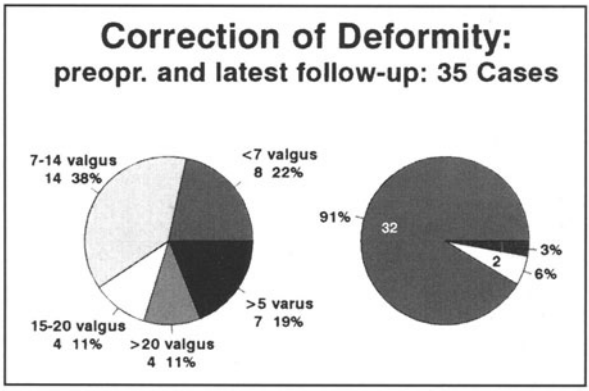


Fig. 31.2



31.3 Discussion

I find that the results of all these analyses speak for themselves. These results are in accordance with the results of others who have used second-generation ankle arthroplasty [4]. The general attitude towards ankle arthroplasty has changed in many orthopaedic centres and it seems that ankle arthroplasty is approaching a new era. It may eventually have results as good as those of other weight-bearing joints. However, it is more demanding to replace the ankle than the other weight-bearing joints. This is partly caused by its more complicated anatomy and kinematics, and partly because it is difficult for most surgeons to acquire enough cases. The risk is, therefore, to stay on the learning curve forever.

References

1. Hamblen DL (1985) Can the ankle joint be replaced? (editorial) J Bone Joint Surg Br 67:689–690
2. Murray WR, Pfeffinger LL, Teasdale RD (1981) Total ankle arthroplasty: a joint too far. J Bone Joint Surg Br 63:459
3. Kofoed H, Stürup J (1994) Comparison of ankle arthroplasty and arthrodesis. Foot 4:6–9
4. Buechel FF, Pappas IM (1992) Survivorship and clinical evaluation of cemented, meniscal-bearing total ankle replacements. Semin Arthroplasty 3:43–50

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